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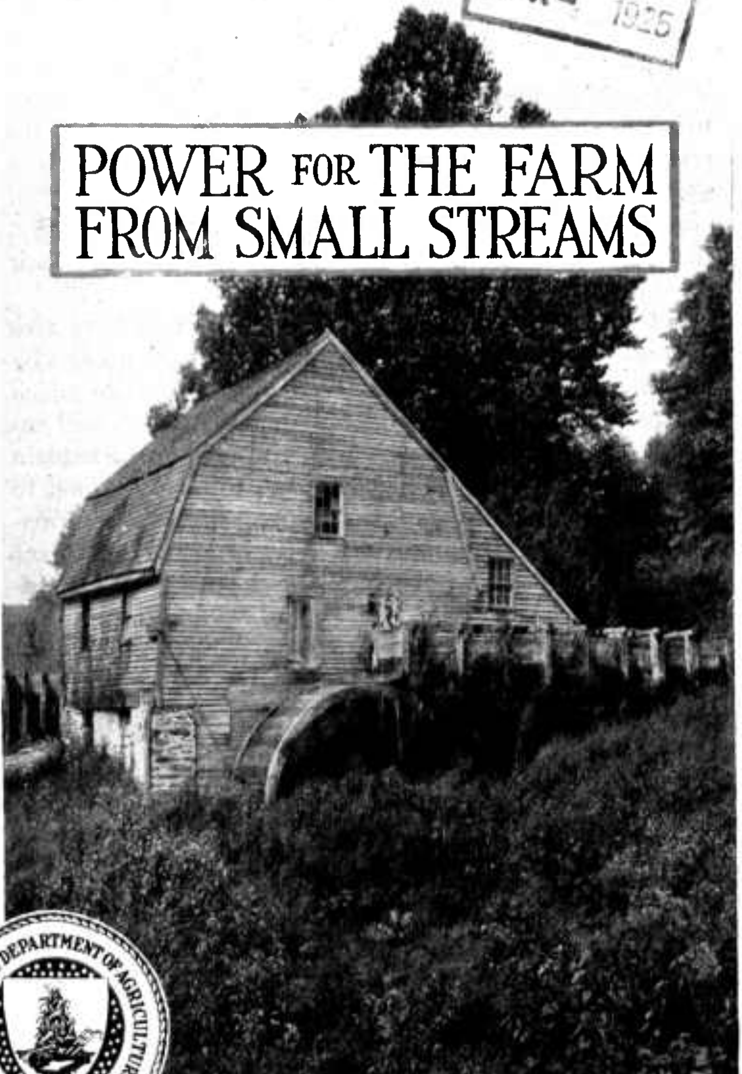
POWER FOR THE FARM FROM SMALL STREAMS



MANY FARMERS do not realize that small streams are frequently sources of power which may be utilized in generating electricity to light their buildings and grounds and possibly to operate a number of small machines. Electrical equipment on the farm saves time and labor in the performance of household and farm work, but if it is to be a sound investment the cost of installation should not, of course, be greater than the benefits obtained will justify. In this respect farm water-power electric outfits have their limitations.

The purpose of this bulletin is to acquaint farmers with the possibilities of developing the power of small streams by converting it into electrical energy and the uses to which such power can be put; to give information which will enable them to avoid unnecessary expenditures; to explain how to determine the power a stream will supply; and to indicate the sources from which to secure additional information in regard to the approximate cost of installing a plant suited to the power available. The details of design, installation, and operation of electrical equipment are not within the scope of this bulletin.

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POWER FOR THE FARM FROM SMALL STREAMS

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CONTENTS

SMALL STREAMS AS SOURCES OF ELECTRIC POWER

MANY STREAMS apparently too small to produce power for practical purposes may be so developed as to furnish enough power for the common needs of the farm; others may provide sufficient power to electrify an entire farm.

Electric power makes possible the use of many labor-saving devices and conveniences. Sometimes the power available will be sufficient for only a few lights. Often, however, plants may be installed large enough to supply from 2 to 5 horsepower during the entire year, and this will meet the requirements of the average farm. In exceptional cases it is possible to provide a plant capable of furnishing 50 to 100 lights and current for operating a washing machine, iron, vacuum cleaner, electric fan, toaster, percolator, sewing machine, a cooking range, etc., as well as such farm machinery as wood saws, corn shellers, and threshers.

Whether it will be profitable to develop a particular power site should be determined before any expense is incurred, and the question is one which the owner must decide for himself. He can determine the amount of available power by methods described in this bulletin and can form an estimate of the power required for each of various operations. From manufacturers of wheels, generators, batteries, etc., he can ascertain the cost of the equipment which must be purchased. He can form an approximate estimate of the cost of a dam, flume, and other construction work. Against this total cost—or the interest on the sum—he must weigh the advantages to be gained. Many of these, such as the greater convenience, can not be estimated in dollars and cents, but time and labor saved by doing many things with electric power can be valued approximately. If that time and labor can be utilized profitably in other ways their value may be credited to the cost of installation.

The first cost of a small water-power plant is usually greater than that of a similar plant driven by an engine, but the operating cost of the former is less, and its depreciation is slower. Sometimes an abandoned milldam can be repaired, and by the installation of the proper machinery electricity can be supplied to a group of farms at a reasonable cost. Such an undertaking may be developed as a cooperative enterprise, or the owner of the site may supply himself with current and sell the surplus to his neighbors. However, small streams do not usually offer opportunity for such development. If it is necessary to construct a dam of considerable size, the return usually will not justify the expense.

Electric plants run by water power can not be bought set-up and ready to work; each plant must be designed to fit the local conditions. Although the average owner can do most if not all of the construction work, the advice of some one familiar with water-power development should be secured. Information of this sort can be obtained from the State agricultural colleges, and the United States Department of Agriculture. Manufacturers of water-power apparatus also are glad to extend assistance to anyone seriously considering a project. They are usually prepared to supply a descriptive booklet containing general information on developing water power, accompanied by a questionnaire, so that the owner may submit data relating to the project and thus enable the manufacturer to recommend the most suitable machinery and advise as to its cost. This service is free of charge. If an order is placed, manufacturers will usually prepare a complete general arrangement drawing without extra charge, showing how the apparatus should be set and giving the dimensions of the required equipment. In some cases the purchaser is advised as to the successive steps to pursue when installing the machinery in order to secure the best results. The services of an expert erecting engineer will be furnished if desired for a stipulated amount per day plus living and traveling expenses, but for small installations the cost will usually prohibit the employment of such help, and generally it is not required.

The farmer who attempts to construct a plant without full knowledge of the requirements is apt to incur needless expense, and in some cases complete failure may result. As an illustration, a Maryland farmer purchased "a complete secondhand water power outfit" advertised in a farm paper with the idea of installing it on a small brook. The material was received in good condition and was exactly as advertised. As the purchaser did not know how to install it, he secured the assistance of an engineer familiar with small water-power development who returned the disappointing report that the greater part of the equipment was not suited to the particular stream and that the electric generator required a stream capable of supplying five times the power that could be obtained.

POWER

The power that can be obtained from falling water depends upon the volume of water which passes a given point in one minute and the height through which the water falls. The power afforded by the falling water is expressed in horsepower. The volume of water

passing is usually expressed in cubic feet per minute and the height of fall, or head (fig. 1), in feet. Table 1 will enable the farmer to determine the volume of water after he has made simple measurements of the velocity of the stream and its cross-sectional area by methods that will be later described and the height of fall can be measured directly. Knowing the volume of water and height of fall, from Table 2 he can find the horsepower that can be developed from the stream, disregarding power losses that occur when water power is

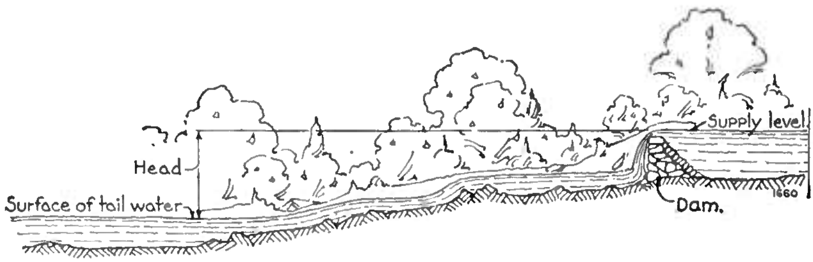

FIG. 1.—Head of water. The useful fall is that distance between the supply level and the surface of the tail-water

converted into electric power. In estimating the electric power at the points of application, it is best to divide the horsepower given in the table by two so as to allow for all conversion and transmission losses. The value thus obtained may be considered a conservative basis for rough calculation and will not necessarily indicate the exact amount of power that may be utilized. The efficiencies of the different units and the transmission losses will determine the relation between the water power and the actual electrical energy available for lighting and other farm uses.

TABLE 1.—*Cubic feet of water per minute*

Cross-section area (square feet)	Average velocity in feet per second (taken as eight-tenths surface velocity)									
	½ foot	1 foot	1½ feet	2 feet	2½ feet	3 feet	3½ feet	4 feet	4½ feet	5 feet
1	30	60	90	120	150	180	210	240	270	300
2	60	120	180	240	300	360	420	480	540	600
3	90	180	270	360	450	540	630	720	810	900
4	120	240	360	480	600	720	840	960	1, 080	1, 200
5	150	300	450	600	750	900	1, 050	1, 200	1, 350	1, 500
6	180	360	540	720	900	1, 080	1, 260	1, 440	1, 620	1, 800
7	210	420	630	840	1, 050	1, 260	1, 470	1, 680	1, 890	2, 100
8	240	480	720	960	1, 200	1, 440	1, 680	1, 920	2, 160	2, 400
9	270	540	810	1, 080	1, 350	1, 620	1, 890	2, 160	2, 430	2, 700
10	300	600	900	1, 200	1, 500	1, 800	2, 100	2, 400	2, 700	3, 000
12	360	720	1, 080	1, 440	1, 800	2, 160	2, 520	2, 880	----	----
14	420	840	1, 260	1, 680	2, 100	2, 520	2, 940	----	----	----
16	480	960	1, 440	1, 920	2, 400	2, 880	----	----	----	----
18	540	1, 080	1, 620	2, 160	2, 700	----	----	----	----	----
20	600	1, 200	1, 800	2, 400	3, 000	----	----	----	----	----
22	660	1, 320	1, 980	2, 640	----	----	----	----	----	----
24	720	1, 440	2, 160	2, 880	----	----	----	----	----	----
26	780	1, 560	2, 340	----	----	----	----	----	----	----
28	840	1, 680	2, 520	----	----	----	----	----	----	----
30	900	1, 800	2, 700	----	----	----	----	----	----	----
35	1, 050	2, 100	----	----	----	----	----	----	----	----
40	1, 200	2, 400	----	----	----	----	----	----	----	----
45	1, 350	2, 700	----	----	----	----	----	----	----	----
50	1, 500	3, 000	----	----	----	----	----	----	----	----

TABLE 2.—*Horsepower based on measured flow and head*

Flow (cubic feet per minute)	Head in feet																		
	2	3	4	5	6	7	8	9	10	12	14	16	18	20	25	30	35	40	50
6	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	0.5	0.6
8	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	0.5	.6	.8
10	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	0.6	.7	.8	1.0
12	----	----	----	----	----	----	----	----	----	----	----	----	----	----	0.6	.7	.8	.9	1.1
14	----	----	----	----	----	----	----	----	----	----	----	----	----	----	.7	.8	.9	1.1	1.3
15	----	----	----	----	----	----	----	----	----	----	----	----	0.5	0.6	.7	.9	1.0	1.1	1.4
20	----	----	----	----	----	----	----	----	----	----	0.5	0.6	.7	.8	1.0	1.1	1.3	1.5	1.9
25	----	----	----	----	----	----	----	----	----	0.6	.7	.8	.9	1.0	1.2	1.4	1.7	1.9	2.4
30	----	----	----	----	----	----	----	0.5	0.6	.7	.8	.9	1.0	1.1	1.4	1.7	2.0	2.3	2.8
35	----	----	----	----	----	----	0.5	.6	.7	.8	.9	1.1	1.2	1.3	1.7	2.0	2.4	2.7	3.3
40	----	----	----	----	----	0.5	.6	.7	.7	.9	1.1	1.2	1.4	1.5	1.9	2.3	2.7	3.0	3.8
45	----	----	----	----	----	.6	.7	.8	.9	1.0	1.2	1.4	1.5	1.7	2.1	2.6	3.0	3.4	4.3
50	----	----	----	----	0.6	.7	.8	.9	1.0	1.1	1.3	1.5	1.7	1.9	2.4	2.8	3.3	3.8	4.7
55	----	----	----	----	.6	.7	.8	.9	1.0	1.3	1.5	1.7	1.9	2.1	2.6	3.1	3.6	4.2	5.2
60	----	----	----	0.6	.7	.8	.9	1.0	1.1	1.4	1.6	1.8	2.0	2.3	2.8	3.4	4.0	4.5	5.7
65	----	----	----	.6	.7	.9	1.0	1.1	1.2	1.5	1.7	2.0	2.2	2.5	3.1	3.7	4.3	4.9	6.1
70	----	----	----	.7	.8	.9	1.1	1.2	1.3	1.6	1.9	2.1	2.4	2.7	3.3	4.0	4.6	5.3	6.6
75	----	----	0.6	.7	.9	1.0	1.1	1.3	1.4	1.7	2.0	2.3	2.6	2.8	3.5	4.3	5.0	5.7	7.1
80	----	----	.6	.8	.9	1.1	1.2	1.4	1.5	1.8	2.1	2.4	2.7	3.0	3.8	4.5	5.3	6.1	7.6
85	----	----	.6	.8	1.0	1.1	1.3	1.5	1.6	1.9	2.3	2.6	2.9	3.2	4.0	4.8	5.6	0.4	8.0
90	----	----	.7	.9	1.0	1.2	1.4	1.5	1.7	2.0	2.4	2.7	3.1	3.4	4.3	5.1	6.0	6.8	8.5
95	----	----	.7	.9	1.1	1.3	1.4	1.6	1.8	2.2	2.5	2.9	3.2	3.6	4.5	5.4	6.3	7.2	9.0
100	----	0.6	.8	1.0	1.1	1.3	1.5	1.7	1.9	2.3	2.7	3.0	3.4	3.8	4.7	5.7	6.6	7.6	9.5
110	----	.6	.8	1.0	1.3	1.5	1.7	1.9	2.1	2.5	2.9	3.3	3.7	4.2	5.2	6.2	7.3	8.3	10.4
120	----	.7	.9	1.1	1.4	1.6	1.8	2.0	2.3	2.7	3.2	3.6	4.1	4.5	5.7	6.8	7.9	9.1	11.3
130	----	.7	1.0	1.2	1.5	1.7	2.0	2.2	2.5	3.0	3.4	3.9	4.4	4.9	6.1	7.4	8.6	9.8	12.3
140	----	.8	1.1	1.3	1.6	1.9	2.1	2.4	2.7	3.2	3.7	4.2	4.8	5.3	6.6	7.9	9.3	10.6	13.2
150	0.6	.9	1.1	1.4	1.7	2.0	2.3	2.6	2.8	3.4	4.0	4.5	5.1	5.7	7.1	8.5	9.9	11.3	14.2
160	.6	.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0	3.6	4.2	4.8	5.4	6.1	7.6	9.1	10.6	12.1	15.1
170	.6	1.0	1.3	1.6	1.9	2.3	2.6	2.9	3.2	3.9	4.5	5.1	5.8	6.4	8.0	9.6	11.2	12.9	16.1
180	.7	1.0	1.4	1.7	2.0	2.4	2.7	3.1	3.4	4.1	4.8	5.4	6.1	6.8	8.5	10.2	11.9	13.6	17.0
190	.7	1.1	1.4	1.8	2.2	2.5	2.9	3.2	3.6	4.3	5.0	5.8	6.5	7.2	9.0	10.8	12.6	14.4	18.0
200	.8	1.1	1.5	1.9	2.3	2.7	3.0	3.4	3.8	4.5	5.3	0.1	6.8	7.6	9.5	11.4	13.2	15.1	18.9
220	.8	1.3	1.7	2.1	2.5	2.9	3.3	3.7	4.2	5.0	5.8	6.7	7.5	8.3	10.4	12.5	14.6	16.6	20.8
240	.9	1.4	1.8	2.3	2.7	3.2	3.6	4.1	4.5	5.4	6.4	7.3	8.2	9.1	11.3	13.6	15.9	18.1	----
260	1.0	1.5	2.0	2.5	3.0	3.4	3.9	4.4	4.9	5.9	6.9	7.9	8.9	9.8	12.3	14.7	17.2	19.7	----
280	1.1	1.6	2.1	2.7	3.2	3.7	4.2	4.8	5.3	6.4	7.4	8.5	9.5	10.6	13.2	15.9	18.5	----	----
300	1.1	1.7	2.3	2.8	3.4	4.0	4.5	5.1	5.7	6.8	7.9	9.1	10.2	11.3	14.2	17.0	19.8	----	----
325	1.2	1.8	2.5	3.1	3.7	4.3	4.9	5.5	6.1	[illegible]	8.6	9.8	11.1	12.3	15.4	18.4	----	----	----
350	1.3	2.0	2.7	3.3	4.0	4.6	5.3	6.0	6.6	7.9	9.3	10.6	11.9	13.2	16.5	19.8	----	----	----
375	1.4	2.1	2.8	3.5	4.3	5.0	5.7	6.4	7.1	8.5	9.9	11.3	12.8	14.2	17.7	21.3	----	----	----
400	1.5	2.3	3.0	3.8	4.5	5.3	6.1	6.8	7.6	9.1	10.6	12.1	13.6	15.1	18.9	22.7	----	----	----
425	1.6	2.4	3.2	4.0	4.8	5.6	6.4	7.2	8.0	9.6	11.2	12.9	14.5	16.1	20.1	24.1	----	----	----
450	1.7	2.6	3.4	4.3	5.1	6.0	6.8	7.7	8.5	10.2	11.9	13.6	15.3	17.0	21.3	25.5	----	----	----
475	1.8	2.7	3.6	4.5	5.4	6.3	7.2	8.1	9.0	10.8	12.6	14.4	16.2	18.0	22.4	----	----	----	----
500	1.9	2.8	3.8	4.7	5.7	6.6	7.6	8.5	9.5	11.3	13.2	15.1	17.0	18.9	23.6	----	----	----	----
525	2.0	3.0	4.0	5.0	6.0	7.0	7.9	8.9	9.9	11.9	13.9	15.9	17.9	19.8	24.8	----	----	----	----
550	2.1	3.1	4.2	5.2	6.2	7.3	8.3	9.4	10.4	12.5	14.6	16.6	18.7	20.8	26.0	----	----	----	----
575	2.2	3.3	4.4	5.4	6.5	7.6	8.7	9.8	10.9	13.0	15.2	17.4	19.6	21.7	27.2	----	----	----	----
600	2.3	3.4	4.5	5.7	6.8	7.9	9.1	10.2	11.3	13.6	15.9	18.1	20.4	22.7	----	----	----	----	----
025	2.4	3.5	4.7	5.9	7.1	8.3	9.5	10.6	11.8	14.2	16.5	18.9	21.3	23.6	----	----	----	----	----
650	2.5	3.7	4.9	6.1	7.4	8.6	9.8	11.1	12.3	14.7	17.2	19.7	22.1	24.6	----	----	----	----	----
675	2.6	3.8	5.1	6.4	7.7	8.9	10.2	11.5	12.8	15.3	17.9	20.4	23.0	25.5	----	----	----	----	----
700	2.7	4.0	5.3	6.6	7.9	9.3	10.6	11.9	13.2	15.9	18.5	21.2	23.8	26.5	----	----	----	----	----
725	2.7	4.1	5.5	6.9	8.2	9.6	11.0	12.3	13.7	16.4	19.2	22.0	24.7	27.4	----	----	----	----	----
750	2.8	4.3	5.7	7.1	8.5	9.9	11.3	12.8	14.2	17.0	19.8	22.7	25.5	----	----	----	----	----	----
775	2.9	4.4	5.9	7.3	8.8	10.3	11.7	13.2	14.6	17.6	20.5	23.4	26.4	----	----	----	----	----	----
800	3.0	4.5	6.1	7.6	9.1	10.6	12.1	13.6	15.1	18.1	21.2	24.2	27.2	----	----	----	----	----	----
825	3.1	4.7	6.2	7.8	9.4	10.9	12.5	14.0	15.6	18.7	21.8	24.9	28.1	----	----	----	----	----	----
850	3.2	4.8	6.4	8.0	9.6	11.2	12.9	14.5	16.1	19.3	22.5	25.7	28.9	----	----	----	----	----	----
875	3.3	5.0	0.6	8.3	9.9	11.6	13.2	14.9	16.5	19.8	23.2	26.5	29.8	----	----	----	----	----	----
900	3.4	5.1	6.8	8.5	10.2	11.9	13.6	15.3	17.0	20.4	23.8	27.2	30.6	----	----	----	----	----	----
950	3.6	5.4	7.2	9.0	10.8	12.6	14.4	16.2	18.0	21.5	25.1	28.7	----	----	----	----	----	----	----
1,000	3.8	5.7	7.6	9.5	11.3	13.2	15.1	17.0	18.9	22.7	26.5	30.2	----	----	----	----	----	----	----
1,100	4.2	6.2	8.3	10.1	12.5	14.6	16.6	18.7	20.8	24.9	29.1	33.3	----	----	----	----	----	----	----
1,200	4.5	6.8	9.1	11.3	13.6	15.9	18.1	20.4	22.7	27.2	31.8	36.3	----	----	----	----	----	----	----
1,300	4.9	7.3	9.8	12.3	14.7	17.2	19.7	22.1	24.6	29.5	34.4	39.3	----	----	----	----	----	----	----
1,400	5.3	7.9	10.6	13.2	15.9	18.5	21.2	23.8	26.5	31.8	37.0	42.3	----	----	----	----	----	----	----
1,500	5.7	8.5	11.3	14.2	17.0	19.8	22.7	25.5	28.4	34.0	39.7	----	----	----	----	----	----	----	----
1,600	0.0	9.1	12.1	15.1	18.1	21.2	24.2	27.2	30.2	36.3	42.3	----	----	----	----	----	----	----	----
1,700	6.4	9.6	12.9	16.1	19.3	22.5	25.7	28.9	32.1	38.6	45.0	----	----	----	----	----	----	----	----
1,800	6.8	10.2	13.6	17.0	20.4	23.8	27.2	30.6	34.0	40.8	47.6	----	----	----	----	----	----	----	----
1,900	7.2	10.8	14.4	18.0	21.5	25.1	28.7	32.3	35.9	43.1	50.3	----	----	----	----	----	----	----	----
2,000	7.6	11.3	15.1	18.9	22.7	26.5	30.2	34.0	37.8	45.4	----	----	----	----	----	----	----	----	----
2,200	8.3	12.5	16.6	20.8	24.9	29.1	33.3	37.4	41.6	50.0	----	----	----	----	----	----	----	----	----
2,400	9.1	13.6	18.1	22.7	27.2	31.8	36.3	40.8	45.4	54.4	----	----	----	----	----	----	----	----	----
2,600	9.8	14.7	19.7	24.6	29.5	34.4	39.3	44.2	49.1	59.0	----	----	----	----	----	----	----	----	----
2,800	10.6	15.9	21.2	26.5	31.8	37.0	42.3	47.6	52.9	----	----	----	----	----	----	----	----	----	----
3,000	11.3	17.0	22.7	28.4	34.0	39.7	45.4	51.0	56.7	----	----	----	----	----	----	----	----	----	----

DETERMINING THE FEASIBILITY OF WATER-POWER DEVELOPMENT

A preliminary survey and estimate is essential in ascertaining whether the project is feasible. This should consist of (1) determination of the power available as explained above; (2) determination of the height and length of dam required, if any, and the probable effect of backwater upon adjoining farms; (3) comparison of the power available with the power required; (4) location and type of plant.

The measurement of the water and the head can be made with sufficient accuracy by the owner of the site, and usually he will be able to secure the other data. If the owner is not able to use a surveyor's level and is not sufficiently versed in the subject to make the best selection for the power and dam site and to decide upon equipment that will be the most suitable, it will be advisable to secure the assistance of an engineer familiar with such work before ordering material or beginning construction. The setting of a small wheel involves no great difficulty and can usually be done satisfactorily by the owner who follows carefully the instructions supplied by the manufacturer.

MEASURING THE STREAM FLOW

The particular object in measuring the flow of the stream is to determine the smallest amount of water that may be expected at any time during a period of years, as this is usually the controlling factor in designing a plant. The measurement of the flow of a stream should be reasonably accurate, but attempts to secure extreme accuracy are a waste of time, since the flow varies from day to day, season to season, and year to year. The measurement of a stream for a single day may be worth very little, and for this reason it is advisable where possible to make frequent measurements and record each with the date. If, however, only a few measurements can be taken, the flow to be expected at other times of the year may be approximately ascertained by questioning persons who have lived near the stream for a number of years and remember the extreme low and high water stages. The best time to obtain an idea of the power possibilities of a particular stream is during a low-water stage following an extended dry period.

In measuring the volume a fairly straight course of the stream should be selected, with a uniform cross section and free from cross currents, backwater, or eddies. The volume of water may be measured either by the cross-section-velocity method or by weir measurement.

CROSS-SECTION-VELOCITY METHOD

At the upper end of the course two poles should be placed on opposite sides of the stream as shown at A and B, Figure 2, so that a line stretched across between the poles will be at right angles to the direction of stream flow. At the lower end of the course two other poles, C and D, should be similarly placed. The length of the poles will depend on the height of the banks, but they should be long enough when driven into place to hold the lines in a horizontal position near the surface of the water. The distance between these lines should be governed by the velocity of the water; for a slow stream 50 feet will be sufficient, while for a swift stream the length of the course should be from 100 to 200 feet.

The distance between the upper and lower lines on each side of the stream should next be measured accurately with a tape; the average of these two measurements may then be taken as the approximate distance between the lines.

The rate at which the water is flowing is determined by means of a float. A lemon makes a good float, or a croquet ball may be used. The float should be placed in the water a sufficient distance above the upper line so that by the time it passes under the line AB (fig. 2) its velocity will be the same as that of the surface of the stream.

The time required for the float to pass from the upper to the lower line should be carefully noted. Several trials should be made with the same float, starting it at various distances from the shore. The average time in seconds required for the float to pass between the lines may then be determined and this time, divided by the distance in feet, gives the velocity of the surface of the stream in feet per second. The velocity of a stream is usually greatest just below the

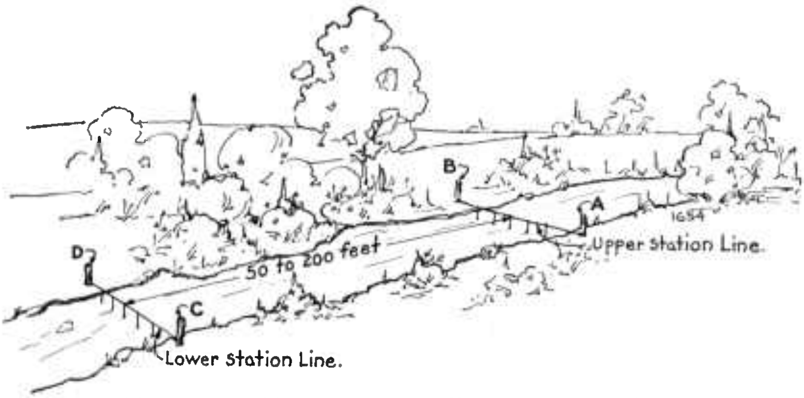

FIG. 2.—Stream measurement, cross-section-velocity method. This method is used where the width of the stream is such that it is impracticable to set a weir (see fig. 4)

surface and least near the bottom and banks. The average velocity of the entire stream is approximately eight-tenths of the surface velocity as determined by float measurements.

Having determined the average velocity in this manner the cross-sectional area of the stream must be measured. This may be done by attaching tags to the lines at equal intervals (see fig. 3) and measuring the depth of water under each tag. The average depth in feet multiplied by the width in feet gives the approximate cross-sectional area in square feet. Cross-sectional measurements should be made at both stations and averaged.

The flow of the stream in cubic feet per minute can then be found by referring to Table 1. In the vertical column corresponding to the average velocity of flow and on the horizontal line for the cross-sectional area most nearly agreeing with that of the stream the number of cubic feet of water per minute will be found.

WEIR METHOD

A weir is a device for measuring flowing water and consists of a vertical wall having at the top a notch through which the water flows.

There are several types of weirs, but the rectangular weir shown in Figure 4 is commonly used for measuring small streams.

The crest or lower edge of the notch of a rectangular weir CD (fig. 4), must be horizontal and the sides AC and BD vertical. It is essential for accurate results that the following conditions be observed.

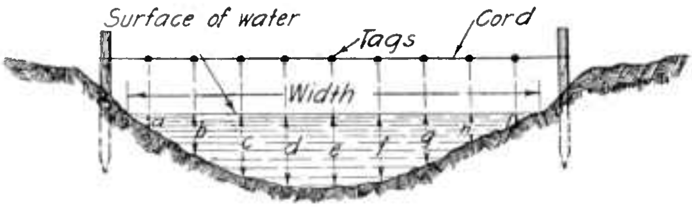

FIG. 3.—Cross-sectioning a stream. Directly under equally spaced points along a cord stretched from bank to bank the depth of water is measured and from these readings the approximate cross-sectional area of the stream may be determined

The length of the notch, AB, should be three to four times the depth of water over the crest. The distance of the ends of the crest from the banks should be at least twice this depth of water and the distance from the stream bed to the crest of the weir should be at least three times this depth of water. To secure these proportions it may be necessary to set a test weir in order to get an idea of the depth of water

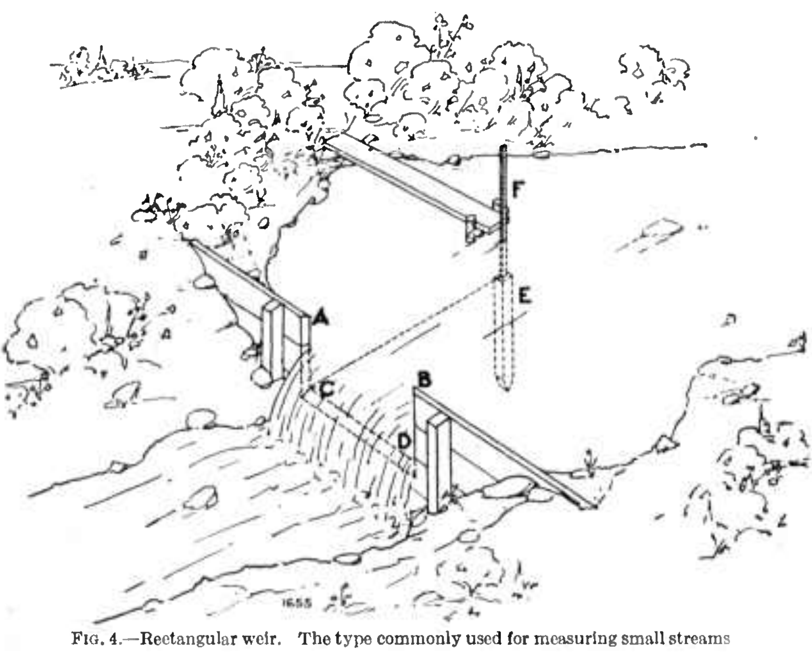

FIG. 4.—Rectangular weir. The type commonly used for measuring small streams

on the weir for the width selected. The tentative width of the notch may first be made two-thirds of the width of the stream at the weir site. The notch should be beveled about 45° to within one-eighth inch of the upstream face, so that the edge will be almost sharp. The water as it flows over the weir should be free to fall without touching the wall

below or any obstruction which might interfere with free circulation of air underneath the falling water. The water above the weir should be practically still and in order to secure this condition it may be necessary to widen and deepen the stream.

The weir should be located, if possible, where fairly large stones are plentiful and where the soil along the banks directly above the weir site is clayey rather than sandy. Two position stakes (fig. 4) should be driven in place, or several large stones or rocks should be planted near each bank, and the weir should be set into the bank so as to bear against them. The weir should then be leveled to the desired position. When the weir is staked and leveled heavy rocks should be placed on the lower side to hold it securely, care being taken that no rocks directly behind the weir notch project above the downstream water surface. Clay or sod should then be placed on the upper side of the weir, beginning at each side and working to the center, until there is no leakage around or under it. Before the water on the upstream side has risen to the level of the weir crest a measuring stake, E (fig. 4), should be driven in the bottom of the pond at a point about six feet above the weir and a carpenter's level used to set the top of the stake level with the crest of the weir. The dam should then be completed so as to force all the water through the notch.

If the bed of the stream is soft, and rocks or stones are not available for anchoring the weir, stakes long enough to hold the weir firmly in place must be driven into the stream bed. Special precautions should be taken to prevent seepage under the dam and undermining on the downstream side. Both may be avoided by setting the weir on a firmly anchored wooden floor extending a short distance above and below it. The ends and sides of the flooring should be made water-tight with sods. Another method of insuring water-tightness is to install a weir box [1] in the stream.

A rule, F, held vertically upon the top of the stake E will indicate the depth of water passing over the crest. The quantity can then be obtained by the use of Table 3. If, for example, the depth of water under normal conditions of flow is 8¾ inches on a weir 3 feet long, the quantity in cubic feet per second is found on the horizontal line for 8¾ inches and in the vertical column for 3 feet. This figure is 5.97, which multiplied by 60 represents a flow of 358 cubic feet per minute.

MEASURING THE HEAD

After the quantity of water has been measured the head or fall that can be utilized must be determined before an estimate of the available power can be made.

The difference in elevation between two points along the water's edge may be measured by means of a 10-foot straightedge, such as stone masons use, a carpenter's level, and a 2-foot rule or yardstick. If available, a farm level, an engineer's Y level, or a transit with level attachment and a leveling rod should be used, as the work may then be done more rapidly and accurately.

The course of the stream apparently having the greatest fall in the shortest distance is located. One end of the straightedge, at the center of which the carpenter's level should be securely fastened, is

[1] The construction of a weir box is described in Farmers' Bulletin No. 813 "Construction and Use of Farm Weirs."

placed at the water level at the upper end of the stretch. The downstream end is raised until the straightedge is level. The vertical distance between the downstream end of the straightedge and the water surface is the fall in the 10-foot length. The straightedge should then be moved downstream, the upper end being placed at the water surface at the spot where the previous measurement was taken and the operation repeated until the lower point of the selected course is reached. The sum of the vertical measurements will be the total fall.

TABLE 3.—*Discharge tables for rectangular weirs*

Head in feet	Head in inches	Discharge in cubic feet per second for crests of various lengths					Head in feet	Head in inches	Discharge in cubic feet per second for crests of various lengths				
		1 foot	1.5 feet	2 feet	3 feet	4 feet			1 foot	1.5 feet	2 feet	3 feet	4 feet
0.20	2 3/8	0.291	0.439	0.588	0.887	1.19	0.86	10 5/16	2.46	3.72	5.01	7.59	10.19
.21	2 1/2	.312	.472	.632	.954	1.28	.87	10 7/16	2.50	3.79	5.10	7.72	10.36
.22	2 5/8	.335	.505	.677	1.02	1.37	.88	10 9/16	2.54	3.85	5.18	7.85	10.54
.23	2 3/4	.358	.539	.723	1.09	1.46	.89	10 11/16	2.58	3.92	5.27	7.99	10.71
.24	2 7/8	.380	.574	.769	1.16	1.55	.90	10 13/16	2.02	3.98	5.35	8.12	10.89
.25	3	.404	.609	.817	1.23	1.65	.91	10 15/16	2.67	4.05	5.44	8.25	11.07
.26	3 1/8	.428	.646	.865	1.31	1.75	.92	11 1/16	2.71	4.11	5.53	8.38	11.25
.27	3 1/4	.452	.682	.914	1.38	1.85	.93	11 3/16	2.75	4.18	5.62	8.52	11.43
.28	3 3/8	.477	.720	.965	1.46	1.95	.94	11 1/4	2.79	4.24	5.71	8.65	11.61
.29	3 1/2	.502	.758	1.02	1.53	2.05	.95	11 3/8	2.84	4.31	5.80	8.79	11.79
.30	3 5/8	.527	.796	1.07	1.61	2.16	.96	11 1/2	2.88	4.37	5.89	8.93	11.98
.31	3 3/4	.553	.836	1.12	1.09	2.26	.97	11 5/8	2.93	4.44	5.98	9.00	12.16
.32	3 13/16	.580	.876	1.18	1.77	2.37	.98	11 3/4	2.97	4.51	6.07	9.20	12.34
.33	3 15/16	.606	.916	1.23	1.86	2.48	.99	17 7/8	3.01	4.57	6.15	9.34	12.53
.34	4 1/16	.634	.957	1.28	1.94	2.60	1.00	12	3.06	4.64	0.25	9.48	12.72
.35	4 3/16	.661	.999	1.34	2.02	2.71	1.01	12 1/8	------	4.71	0.34	9.62	12.91
.36	4 5/16	.688	1.04	1.40	2.11	2.82	1.02	12 1/4	------	4.78	6.43	9.76	13.10
.37	4 7/16	.717	1.08	1.45	2.20	2.94	1.03	12 3/8	------	4.85	6.52	9.90	13.28
.38	4 9/16	.745	1.13	1.51	2.28	3.06	1.04	12 1/2	------	4.92	6.62	10.04	13.47
.39	4 11/16	.774	1.17	1.57	2.37	3.18	1.05	12 5/8	------	4.98	6.71	10.18	13.66
.40	4 13/16	.804	1.21	1.63	2.46	3.30	1.06	12 3/4	------	5.05	6.80	10.32	13.85
.41	4 15/16	.833	1.26	1.69	2.55	3.42	1.07	12 13/16	------	5.12	6.90	10.46	14.04
.42	5 1/16	.863	1.30	1.75	2.65	3.54	1.08	12 15/16	------	5.20	6.99	10.61	14.24
.43	5 3/16	.893	1.35	1.81	2.74	3.67	1.09	13 1/16	------	5.26	7.09	10.75	14.43
.44	5 1/4	.924	1.40	1.88	2.83	3.80	1.10	13 3/16	------	5.34	7.19	10.90	14.64
.45	5 3/8	.955	1.44	1.94	2.93	3.93	1.11	13 5/16	------	5.41	7.28	11.04	14.83
.46	5 1/2	.986	1.49	2.00	3.03	4.05	1.12	13 7/16	------	5.48	7.38	11.19	15.03
.47	5 5/8	1.02	1.54	2.07	3.12	4.18	1.13	13 9/16	------	5.55	7.47	11.34	15.22
.48	5 3/4	1.05	1.59	2.13	3.22	4.32	1.14	13 11/16	------	5.62	7.57	11.48	15.42
.49	5 7/8	1.08	1.64	2.20	3.32	4.45	1.15	13 13/16	------	5.69	7.66	11.64	15.62
.50	6	1.11	1.68	2.26	3.42	4.58	1.16	13 15/16	------	5.77	7.76	11.79	15.82
.51	6 1/8	1.15	1.73	2.33	3.52	4.72	1.17	14 1/16	------	5.84	7.86	11.94	16.02
.52	6 1/4	1.18	1.78	2.40	3.02	4.86	1.18	14 3/16	------	5.91	7.90	12.09	16.23
.53	6 3/8	1.21	1.84	2.46	3.73	4.99	1.19	14 1/4	------	5.98	8.06	12.24	16.43
.54	6 1/2	1.25	1.89	2.53	3.83	5.13	1.20	14 3/8	------	6.06	8.10	12.39	16.63
.55	6 5/8	1.28	1.94	2.60	3.94	5.27	1.21	14 1/2	------	6.13	8.26	12.54	16.83
.56	6 3/4	1.31	1.99	2.67	4.04	5.42	1.22	14 5/8	------	6.20	8.35	12.69	17.03
.57	6 13/16	1.35	2.04	2.74	4.15	5.56	1.23	14 3/4	------	6.28	8.46	12.85	17.25
.58	6 15/16	1.38	2.09	2.81	4.26	5.70	1.24	14 7/8	------	6.35	8.56	12.99	17.45
.59	7 1/16	1.42	2.15	2.88	4.36	5.85	1.25	15	------	6.43	8.66	13.14	17.65
.60	7 3/16	1.45	2.20	2.96	4.47	6.00	1.26	15 1/8	------	------	------	13.30	17.87
.01	7 5/16	1.49	2.25	3.03	4.59	6.14	1.27	15 1/4	------	------	------	13.45	18.07
.62	7 7/16	1.52	2.31	3.10	4.69	6.29	1.28	15 3/8	------	------	------	13.61	18.28
.63	7 9/16	1.56	2.36	3.17	4.81	6.44	1.29	15 1/2	------	------	------	13.77	18.50
.64	7 11/16	1.60	2.42	3.25	4.92	6.59	1.30	15 5/8	------	------	------	13.93	18.71
.65	7 13/16	1.63	2.47	3.32	5.03	6.75	1.31	15 3/4	------	------	------	14.09	18.92
.66	7 15/16	1.67	2.53	3.40	5.15	6.90	1.32	15 13/16	------	------	------	14.24	19.12
.67	8 1/16	1.71	2.59	3.47	5.26	7.05	1.33	15 15/16	------	------	------	14.40	19.34
.68	8 3/16	1.74	2.64	3.56	5.38	7.21	1.34	16 1/16	------	------	------	14.50	19.55
.69	8 1/4	1.78	2.70	3.63	5.49	7.36	1.35	16 3/16	------	------	------	14.72	19.77
.70	8 3/8	1.82	2.76	3.71	5.61	7.52	1.36	16 5/16	------	------	------	14.88	19.98
.71	8 1/2	1.86	2.81	3.78	5.73	7.68	1.37	16 7/16	------	------	------	15.04	20.20
.72	8 5/8	1.90	2.87	3.86	5.85	7.84	1.38	16 9/16	------	------	------	15.20	20.42
.73	8 3/4	1.93	2.93	3.94	5.97	8.00	1.39	16 11/16	------	------	------	15.36	20.64
.74	8 7/8	1.97	2.99	4.02	6.09	8.17	1.40	16 13/16	------	------	------	15.53	20.86
.75	9	2.01	3.05	4.10	6.21	8.33	1.41	16 15/16	------	------	------	15.69	21.08
.76	9 1/8	2.05	3.11	4.18	6.33	8.49	1.42	17 1/16	------	------	------	15.85	21 29
.77	9 1/4	2.09	3.17	4.26	6.45	8.66	1.43	17 3/16	------	------	------	16.02	21.52
.78	9 3/8	2.13	3.23	4.34	6.58	8.82	1.44	17 1/4	------	------	------	16.19	21.74
.79	9 1/2	2.17	3.29	4.42	6.70	8.99	1.45	17 3/8	------	------	------	16.34	21.96
.80	9 5/8	2.21	3.35	4.51	6.83	9.10	1.46	17 1/2	------	------	------	16.51	22.18
.81	9 3/4	2.25	3.41	4.59	6.95	9.33	1.47	17 5/8	------	------	------	16.68	22.41
.82	9 13/16	2.29	3.47	4.67	7.08	9.50	1.48	17 3/4	------	------	------	10.85	22.64
.83	9 15/16	2.33	3.54	4.75	7.21	9.67	1.49	17 7/8	------	------	------	17.01	22.85
.84	10 1/16	2.37	3.60	4.84	7.33	9.84	1.50	18	------	------	------	17.17	23.08
.85	10 3/16	2.41	3.66	4.92	7.46	10.01							

The head may also be measured by using two poles, a straightedge, and a carpenter's level, as indicated in Figure 5. The poles should be several feet long with feet and tenths of feet marked on them. Suppose the difference in elevation between points A and B (fig. 5) is desired. A straightedge, to which a carpenter's level has been fastened, is placed against the poles set in positions 1 and 2. When the level bubble has been brought to the center of the tube, suppose the leveling piece is at the 4-foot mark on the lower and the 2-foot mark on the upper, then the difference in elevation between points A and C will be 2 feet. The first pole is then moved upstream to position 3 and the leveling is repeated. The straightedge may be placed at any height and the difference in the readings at the poles will be the rise in the ground between them. When the series of measurements has been completed, the sum of all the differences will be the total difference, or the head between A and B. Whichever method is used the

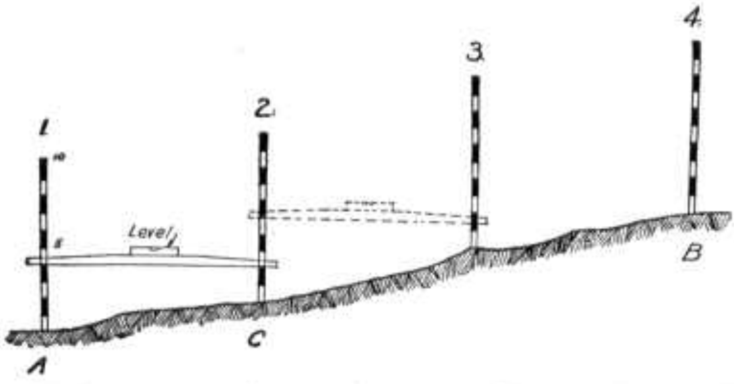

FIG. 5.—The difference in elevation between two points may be determined by using two poles and a carpenter's level as described in the text

measurements should always be taken twice as a check on the accuracy of the work.

If the head found is not sufficient to produce the power needed so that a dam is required, then the point upstream to which the backwater would extend from a dam of a given height can be found by repeating the leveling process until a point is reached that corresponds to the total difference in elevation between A and B plus the additional height required for the dam.

WATER-POWER ELECTRIC PLANTS

The essential characteristics of a water-power electric plant will vary according to conditions at the contemplated site and the demands which the plant must meet. Plants are often designated according to the type of water motor used to drive the generator. Figures 6 and 7, respectively, illustrate the general characteristics of an overshot wheel and a turbine installation. Different types and sizes of water turbines and water wheels are used to suit various conditions of head and flow.

In general it is not advisable to attempt to develop a water-power plant unless the available power is equivalent to that developed by a flow of 30 cubic feet per minute acting under a 10-foot head. If the

FIG. 6.—Farm water-power electric plant with overshot water wheel. A, transmission line; B, power house; C, generator; D, switchboard; E, storage battery; F, flume; G, head gate; H, forebay; I, tail-water; J, tailrace; K, electric line, generator to switchboard; L, water supply control gate; M, overshot water wheel

power is less than that derived from a flow of 100 cubic feet per minute with a 10-foot head, a storage battery is usually necessary. The cost of a battery increases with the voltage required. The maximum

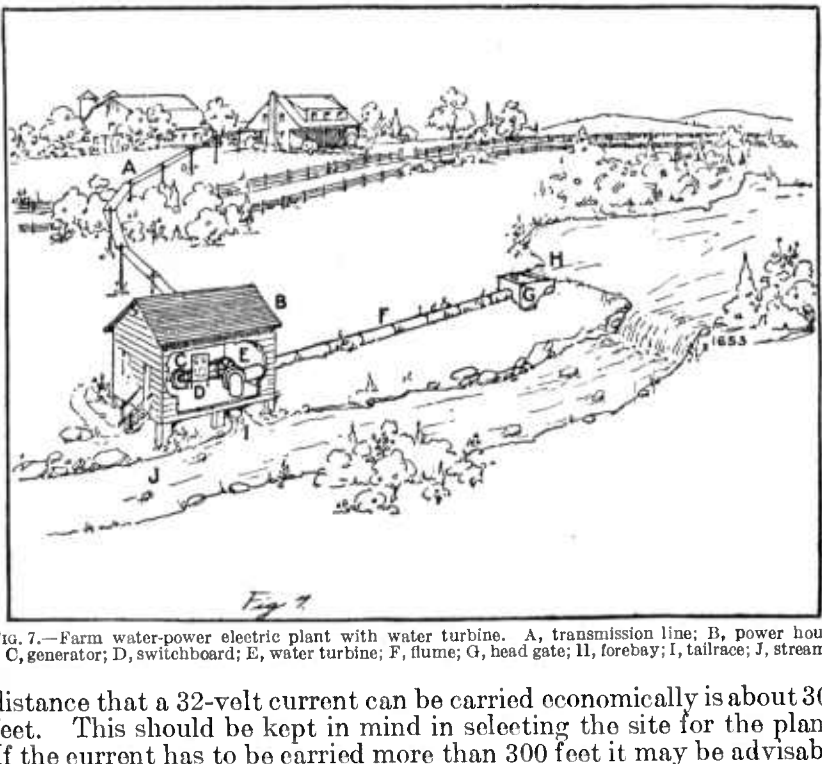

FIG. 7.—Farm water-power electric plant with water turbine. A, transmission line; B, power house; C, generator; D, switchboard; E, water turbine; F, flume; G, head gate; H, forebay; I, tailrace; J, stream

distance that a 32-volt current can be carried economically is about 300 feet. This should be kept in mind in selecting the site for the plant. If the current has to be carried more than 300 feet it may be advisable to install a 32-volt battery and generate current at 40 to 65 volts

so as to compensate for the high voltage drop due to the greater distance, or it may even be necessary to adopt a 110-volt current.

The 32-volt plant requires a battery of 16 lead cells or 26 nickel-iron cells; 56 lead or 92 nickel-iron cells are needed for a 110-volt plant. The approximate cost of cells varies from $5 to $8, depending upon the size and make; hence for a 110-volt battery the cost of the plant will be materially increased. Storage batteries have definite requirements for charging and expert advice should be obtained, so that generator and battery will harmonize. Unless this is done damage may result.

A storage battery consists essentially of one or more cells each composed of two metal plates known, respectively, as positive and negative, with an insulating separator between them, immersed in a liquid called the electrolyte, and all incased in a rubber, glass, or metal container. Storage batteries are of two types, the lead-acid and the nickel-iron alkaline. In the lead plate type the grids or plates are of lead in acid electrolyte, while in the nickel-iron type they are of steel in an alkaline electrolyte. A steel container is used for the nickel-iron cell, the lead-acid container being of rubber or glass. The average voltage of a lead battery when discharging at its normal rate is 2 volts per cell, while each cell of a nickel-iron battery has a voltage of 1.2 volts. In either case the battery voltage is that of one cell multiplied by the number of cells. The capacity of a battery is stated in ampere-hours. A battery whose capacity is 1 ampere-hour will empty a full charge in 1 hour at the rate of 1 ampere or, if the capacity is 120 ampere-hours, it will be capable of supplying current at the rate of 2 amperes for 60 hours or 10 amperes for 12 hours continuously. The nickel-iron battery is preferable to the lead battery. Its cost for the same capacity is considerably greater, but it is less liable to damage due to overcharging or handling and it will last many years longer.

DAMS

If the continuous flow is great enough and the drop is sufficient to give the required head, a small diversion dam will suffice. This may consist of a large tree trunk planted between projecting rocks, with loose stones and earth to stop underflow and to direct the water into the flume conducting the water to the motor. When it is necessary to raise the water level only a few inches or perhaps a foot, temporary dams may be employed. These may consist of sandbags placed across the streams or bundles of brush weighted or staked down, or stones and a few boards. Such dams will leak, sometimes profusely, and may be washed out by a freshet, yet they are often practicable because the cost of renewing them is almost nothing.

If the stream flow is too small for continuous operation, so that it is necessary to store the water for a time in order to have enough to drive the motor for a short period, a substantial dam will be needed. A permanent dam requires careful design and workmanship. It may be built of earth, wood, brush, stone, concrete, or steel, or a combination of two or more of these materials.

The effect of backwater upon adjoining land should be considered carefully so as to avoid trouble resulting from damage to property.

Earth dams are not recommended. If circumstances make it desirable to build this type of dam, it should be built so that water will not flow over it, since this would be almost certain to cause its failure. Accordingly it should be provided with a spillway of sufficient size to pass the entire flow of the stream during floods. This should be located, if possible, at one side of the dam and should be lined with concrete or boards to prevent scouring. Before attempting to build an earth dam expert advice should be obtained from the State agricultural college, the United States Department of Agriculture, or other reliable source.

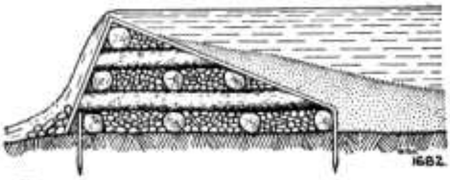

FIG. 8.—Crib dam. For heads not exceeding 6 feet, timbers, placed across one another at intervals of 2 or 3 feet and spiked together, provide substantial construction

The crib dam (figs. 8 and 9) consists of rough and green logs or sawed timbers placed across one another at intervals of 2 or 3 feet and spiked together, the spaces between being filled with stones. The upstream side is covered with planks nailed in place to prevent leakage, and sometimes the downstream face is likewise covered so as to direct the flowing water away from the dam and prevent it from leaking back into the cribbing. Crib dams are sometimes built of logs of different lengths arranged so as to form a series of steps on the downstream side to break the force of the falling water.

FIG. 9.—Crib dam. This construction is recommended for dams more than 6 feet high

Priming planks (see fig. 8) are driven into the stream bed in a row on both the upstream and downstream side to prevent water from seeping under the dam.

Priming planks may be made from 2 by 6 inch rough, sound lumber, free from sap and sharpened by sawing diagnonally across one end. They should be driven firmly into the stream bed and spiked to the crib logs.

If a crib, concrete, or masonry dam is built on bedrock, a rough surface is better than one that it too smooth, as a rough surface prevents possible sliding of the dam on its foundation.

While satisfactory small masonry or concrete dams are often built without the aid of technical advice, such advice usually results in the saving of material and labor. Cut stones or brick should never be used, as a more stable dam can be made by the use of rubble masonry.

If rock is plentiful near the dam site, a substantial masonry dam having its base equal to eight-tenths its height may be built of uncut stones laid in cement mortar. Figure 10 shows the section of a small

masonry dam. If the dam is to be as high as 12 feet, it should not be attempted without the advice of a competent engineer as to design, type, and footing. Even a stream bed of solid rock which appears perfectly safe may be so porous as to threaten the stability of a dam.

Concrete is generally more easily handled than masonry, and its use in the construction of dams is therefore more common. Figure 11 shows a concrete gravity dam in section. Table 4 gives dimensions for several different heights and the quantity of concrete required per foot of width. Concrete[2] for such work should be made of 1 part Portland cement, 2 parts sand, and 4 parts gravel or broken stone. The embedding of large sound stones or bowlders saves concrete. They should be well surrounded by mortar and their total volume should not exceed 30 per cent of the volume of the dam. This dam should not be used for a length greater than 50 feet.

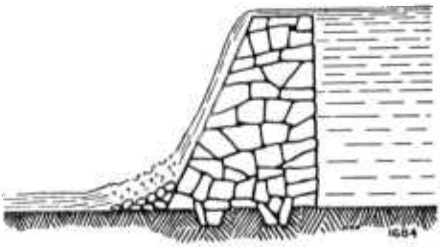

FIG. 10.—Masonry dam. Dams not more than 10 feet high may be built of uncut stones laid in cement mortar. The width of the base should be at least eight-tenths of the height

TABLE 4.—*Dimensions of sections for gravity concrete dams. See Figure 11*

A Height of dam	B	C	D	E	F	Quantity of concrete per foot of width (approximate)
Feet	*Ft. in.*	*In.*	*Ft. in.*	*Ft in.*	*Ft. in.*	*Cu. ft.*
3	1 0	3	1 0	0 9	5 0	10
4	1 3	3	1 0	0 9	6 0	15
5	1 6	3	1 3	0 11	7 3	22
6	1 9	3	1 6	1 1	8 6	31
7	2 0	3	1 9	1 3	9 9	41
8	2 2	3	2 0	1 6	11 0	53
9	2 7	3	2 3	1 9	12 6	67
10	3 0	3	2 6	2 0	14 0	84

THE FLUME

A flume is employed to conduct the water to the water wheel or turbine. The length of the flume will depend upon the topography adjacent to the dam or power site. It may be more economical to construct a long flume in order to secure a sufficient head of water between the dam and power house than to build a high dam with a comparatively short flume. Generally, low diversion dams with long earth flumes are preferable for small stream developments where the slope of the land is gradual enough to permit of this type of flume and of building the power house at a desirable location. If the land falls rather abruptly, the flume may consist of an open, wooden trough supported as shown in Figure 12. If the flume is as much as 4 feet wide, it may be built of 2-inch tongued-and-grooved planks and rested on 3 by 4 inch mudsills laid on the ground which has been

[2] Farmers' Bulletin 1279, "Plain Concrete for Farm Use," contains instructions for preparing and handling concrete.

previously cleared and leveled. Open, rectangular, continuous, wood trough flumes (see fig. 13) 4 feet wide or wider should be braced with 3 by 4 inch studs with three-fourths-inch tie bolts at top and bottom. Wood stave pipe is often used for the flume (see fig. 14), while riveted steel pipe may be required where the head is high. If a pipe line is used, due consideration must be given to the friction head loss. The size of pipe that should be used depends upon the quantity of water that it is to carry and the length of the line.

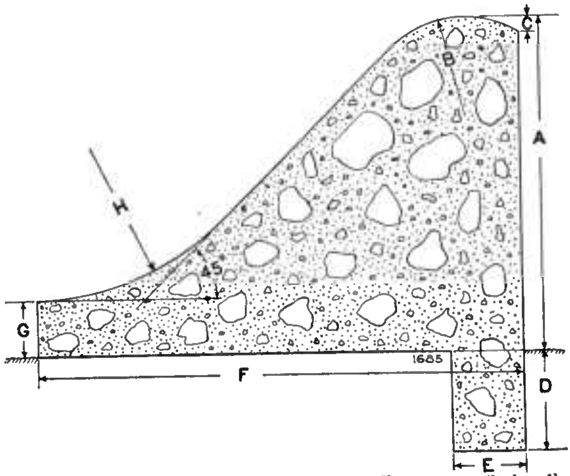

FIG. 11.—Concrete gravity dam. Being generally more easily handled than masonry, the use of concrete is common in dam construction. For dimensions see Table 4

HEAD GATES

Head gates, by means of which the supply of water to the water wheel may be cut off, should be located at the entrance to the channel or flume. The multiple bulkhead gates shown in Figure 15 are more easily opened and closed than a single large gate. It is often advisable to place trash racks or screens just in front of the gates to protect the

FIG. 12.—Small, open, wood trough flume. Properly supported this is a substantial and relatively cheap construction

turbine or wheel. Trash racks are more necessary for turbines than for overshot wheels. They keep out leaves which are apt to become troublesome in the fall of the year, and protect against light trash and ice. Homemade racks are frequently very efficient, but the commercially built rack is apt to be stronger and to permit more water to pass when there is a mass of débris. The trash rack should be designed with regard to the peculiarities of the particular canal, flume, or penstock, and should be set at the angle best suited to the conditions.

A closed pipe through which the water flows under pressure to the motor, as shown at F in Figure 7, is called the penstock. An open

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trough used for the purpose is called a flume. A small body of water at the entrance to a penstock or flume is usually called the forebay or headwater. The tailwater is water that has been discharged from the water motor. The channel or trough through which the water is conducted downstream is called the tailrace.

WATER WHEELS

The power of falling water is converted to use through some type of water wheel. The three general classes of wheels are as follows:

1. Reaction or pressure wheels (reaction turbine).
2. Gravity or current wheels, which include:
   (*a*) Undershot wheels.
   (*b*) Breast wheels.
   (*c*) Overshot wheels.
   (*d*) Pitch-back or high breast wheels.
3. Impulse or velocity wheels (Pelton).

The overshot, impulse, and reaction wheels are the types generally used for small water-power installations.

REACTION TURBINES

The reaction turbine (fig. 16) consists of a number of curved vanes or runners arranged around a central shaft to which they are rigidly connected. The water in flowing through these vanes causes the wheel to rotate. The shaft may be either vertical or horizontal. In addition to the runners the equipment includes the guiding elements and the gate which regulates the supply. The function of the gate is to direct the water to the runners in the proper manner. Swing gates are pivoted guide vanes which act as gates. Another type of gate is the cylinder, which is the cheaper construction but less efficient when partly closed. The power of the wheel is developed by the reaction or pressure of the water as it leaves each blade.

FIG. 13.—Large, open, wood trough flume. Wood flumes of heavy construction should rest upon mudsills laid on the ground, previously cleared and leveled, and should be well braced at top and bottom witb 3 by 4 incb studs and tie bolts

The turbine is controlled by a fly-ball governor, which operates to close the gate if the load is reduced or to open it if the load is increased.

Turbines may be mounted in wood or concrete inclosures or in iron or steel cases connected with the penstock. Figure 17 shows a vertical turbine mounted in a wooden flume, the power being transmitted through bevel gears.

The turbine is generally used for medium and low heads and comparatively large quantities of water. Stock turbines can usually be obtained for heads varying from 2 to 80 feet; they are specially designed for higher heads. The efficiency of the smaller sizes is about 70 to 80 per cent with gates wide open.

OVERSHOT WHEELS

The overshot wheel (fig. 18) is suited to heads varying from 4 to 60 feet, but if the head exceeds 20 feet the cost for small installations may be prohibitive. The efficiency of modern steel overshot wheels is 80 to 90 per cent. Wooden overshot wheels are still used to some extent. They cost less than steel wheels, but their life is shorter and their efficiency is lower.

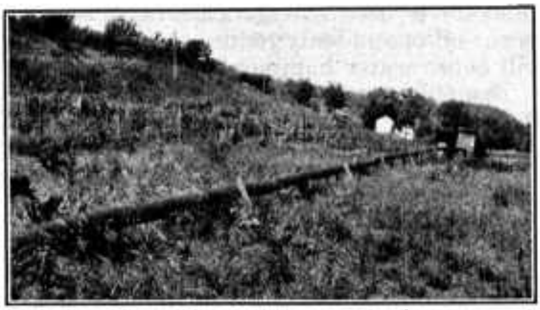

Fig. 14.—Wood stave pipe flume. This type may be quickly installed, but is expensive, especially in the larger sizes

Regulation of overshot wheels is necessary to prevent sudden changes in speed due to variation in load. This is accomplished by means of a fly-ball governor which regulates the water gate according to power requirements. By proportioning the opening of the water gate to the load on the wheel only the water actually required is released while the remainder is conserved. Conservation of water and regulation of speed are essential to the proper operation of small water-power electric plants.

Fig. 15.—Multiple bulkhead flume gates. The smaller units are far easier to operate than a single large gate, and if tightly built will insure equally good stoppage of water

The modern overshot wheel has a definite place in small water-power developments. In the State of Virginia alone more than 1,000 mills and factories are driven by this type of water wheel.

IMPULSE WHEELS

The impulse wheel (fig. 19) is popularly known as the Pelton wheel. It is especially suited for use in mountain sections where the quantity of water is small and the head relatively high or where springs issue from high hillsides. The flow of a small spring may be stored behind an earth dam during the day and operate the wheel at night to generate current for electric lights.

The wheel consists of an iron frame mounted on a horizontal shaft with cup-shaped buckets attached to the rim (fig. 20). The water flows to the wheel through a pipe under pressure. A nozzle at the

end of the pipe directs a jet of water against the buckets, thus turning the wheel.

If the load varies considerably, the speed of the wheel must be governed. In the smaller installations the adjustment for changes of load for short periods is usually made by deflecting the jet of water away from the buckets when the speed becomes excessive. This method wastes water and hand regulation is sometimes preferable. In the larger installations an automatic governor slowly actuating a needle valve provides adjustment for gradual changes of load, and a deflector is used to take care of sudden changes. It is inadvisable to cut off or suddenly reduce the flow in the pipe, since quick stoppage will cause water hammer and may burst the pipe.

The efficiency of the modern impulse wheel is about 80 per cent. It is sold for heads as low as 20 feet but is ordinarily used for heads of over 100 feet. There is apparently no upper limit to the head under which the wheel may operate.

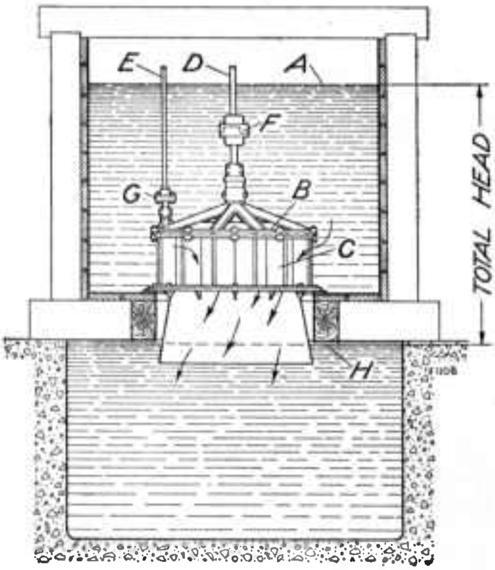

FIG. 16.—Vertical reaction turbine in wooden pit. A, headwater level; B, water turbine; C, wicket guide gates; D, turbine shaft; E, gate control shaft; F, jaw coupling; G, flange coupling; H, tail-water level

TURBINE AND WATER WHEEL CONNECTIONS

A generator or other machinery may be connected to a water motor by means of spur or bevel gears, pulleys and belts, a combination of gears, pulleys, and belts, or when the water-motor speed is practically the same as the required generator speed the two may be direct connected through the same shaft. Owing to the relatively high speed of generators, a belted arrangement will almost invariably be necessary. Gearing may be required in conjunction with the belting, especially where the power generated is sufficient to drive a line shaft from which other machinery may also be driven. Gear transmission is more positive than the belt drive. Efficiencies are about the same so long as the belt is kept in proper condition as to tension, softness, and pliability, and the gearing is kept well lubricated. Belts gradually stretch and provision should be made for tightening them. A satisfactory arrangement is to install a sliding base generator. Generator speeds usually require that the water-motor speed be stepped up considerably. To do this by gearing alone is seldom feasible, owing to the number of pairs of gears required in order to avoid excessively large sizes and the expense incident thereto. The same result usually can be secured by belting with a fairly large pulley on the turbine shaft and a small pulley on the generator shaft. The arrange-

ment of connections must be designed to suit the particular installation. It is not possible to show in this bulletin the many different connections that may be used. In figures 17 and 20 to 29, inclusive, are illustrated a few of the common methods employed.

COMPARISONS OF TURBINE AND OVERSHOT WHEELS

The wheel selected should be suited to the power site, and a careful study of the situation should be made before deciding which type to install.

The flow of all streams varies considerably, and the power plant should be designed to operate on the minimum flow, unless there is provision for storing water to supplement the low flow. For variable stream flow the overshot wheel is ideal. If designed for normal stream flow, it will still deliver a high percentage of the available power during low stream flow; in fact the efficiency of the overshot wheel is slightly higher at low water than at normal periods, because when the buckets are only partially filled the water is carried to a lower level before spilling. The efficiency of a turbine wheel falls rapidly as the supply of water is reduced. An overshot wheel may be used where the flow is insufficient for a turbine wheel, and will therefore provide power for lights and small home conveniences during dry months, and additional power for operating wood saws and other stationary machinery when water is plentiful, while under low-water conditions the quantity might be insufficient to operate a turbine. The overshot wheel is less likely to become clogged with trash and is more efficient than the turbine wheel.

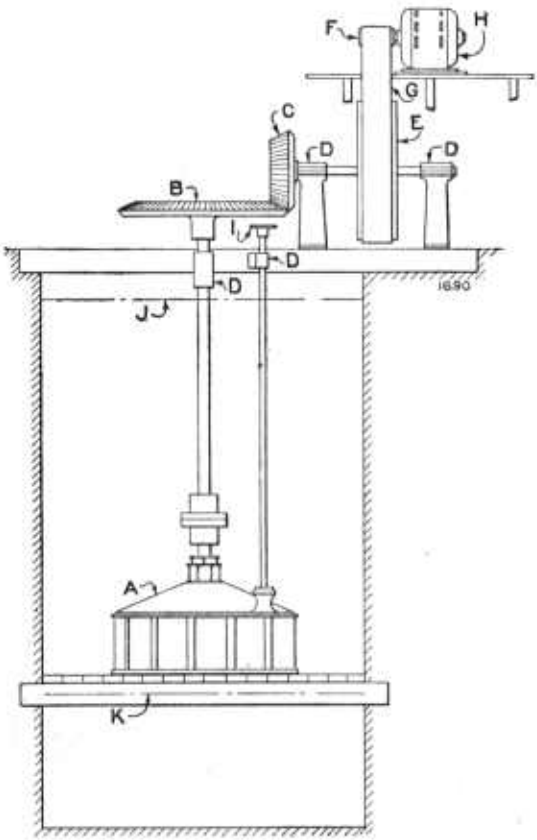

FIG. 17.—Vertical reaction turbine with hand control for driving a small generator through bevel gears and belted pulleys. Where streams are subject to flood, the generator should be set high in order to avoid possible damage from water soaking. A, turbine; B, bevel gear; C, bevel pinion; D, bearing, E, drive pulley; F, generator pulley; G, belt; H, generator; I, hand gate control; J, headwater level; K, tail-water level

The turbine wheel occupies less space than the overshot wheel, and this may sometimes be an advantage. It sets low and may be operated on storage water under a head as low as 75 per cent of the total

head, whereas the overshot wheel can not use water from the storage reservoir below the level of the top of the wheel. The turbine runs at higher speed, which is an asset when it is to drive an electric generator. It will operate submerged. Its cost for the power developed is usually lower than that of the overshot wheel, due principally to the fact that overshot wheels are generally built specially for each installation, while turbines of various sizes are usually carried in stock.

ELECTRIC POWER

Electricity passes through metallic wires or conductors in a manner somewhat analogous to water flowing through pipes. The unit of electrical power is the watt, and 1,000 watts make 1 kilowatt, abbreviated kw. This term is used in rating generators; thus a 2-kw. generator will continuously supply 2,000 watts. One kilowatt is equivalent to 1.34 horsepower.

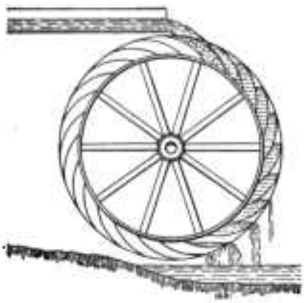

FIG. 18.—Overshot water wheel

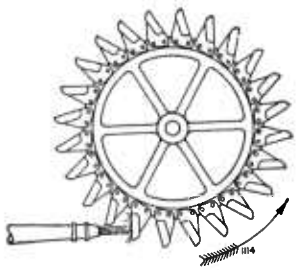

FIG. 19.—Impulse water wheel

Electric generators are of two kinds, direct current (called d. c.) and alternating current (called a. c.). The electricity obtained from a battery or generated by small plants such as are here considered is direct current; that generated by large central stations and distributed to considerable distances is mainly alternating current. Direct current is used as it flows from the generator at comparatively low voltage, 32 or 110 volts, whereas alternating current is generated and flows in the distribution system at high voltage, 6,600 to 11,000 volts and higher. This high-pressure electricity is reduced by means

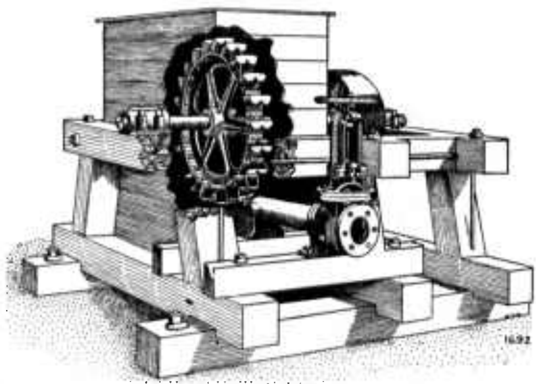

FIG. 20.—Typical impulse water wheel installation with drive pulley

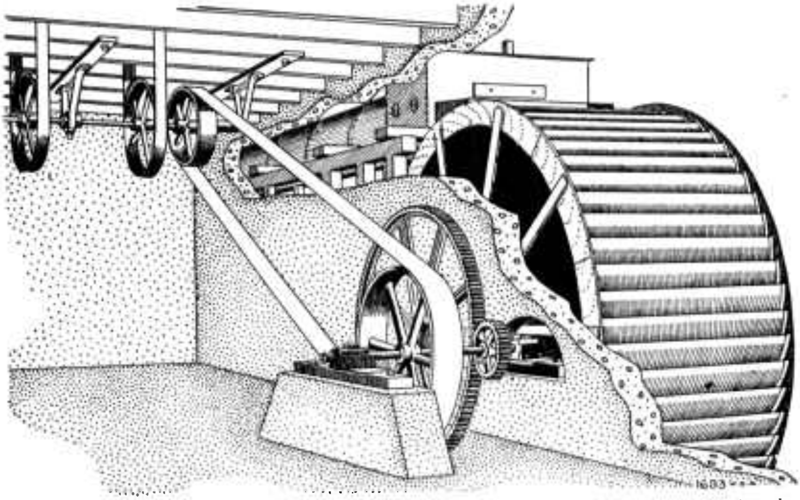

FIG. 21.—Typical overshot water-wheel installation with master spur gear keyed to water-wheel shaft inside the building. A bevel, instead of spur gear, is used if the driven shaft is at right angles to the wheel shaft. Power for driving the generator and other machines is transmitted through the pinion shaft to belted pulleys

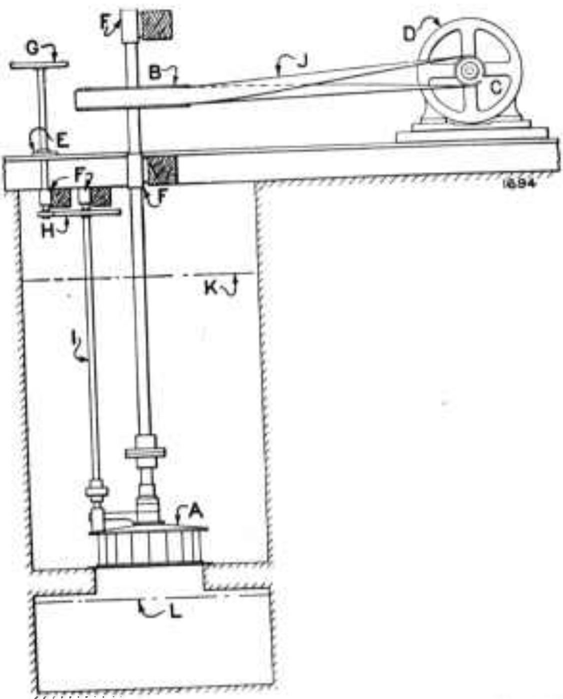

FIG. 22.—Vertical reaction turbine belted direct to generator with hand control. A, turbine; B, drive pulley; C, generator pulley; D, generator; E, ratchet and pawl; F, bearing; G, handwheel control; H, gears; I, gate shaft; J, belt; K, headwater level; L, tail-water level

of a transformer located near the point of application. For lighting purposes either direct or alternating current may be used, but a motor can only be operated by the kind of current for which it is designed.

SIZE OF PLANT REQUIRED

The size of the plant should be determined with regard to both present and future needs. Too much emphasis can not be laid upon the wisdom of providing for a plant of somewhat larger capacity than the needs of the moment seem to indicate if ample power to operate it is available. One or two additional horsepower will not add much to the first cost, and more power is likely to be desired as the conveniences of electricity are appreciated.

TABLE 5.—*Uses of electricity for power*

[Trade data on power requirements]

Device	Power required		Most popular size	
	Horsepower	Watts	Motor horsepower	Watts consumed
Washing machine	1/8 to 1/4	165 to 290	1/4	290
Vacuum cleaner	1/8 to 1/2	165 to 535	1/8	210
Electric fan, 8-inch	1/30	50	1/30	50
Electric fan, 16-inch	1/12	125	1/12	125
Sewing machine	1/30	50	1/30	50
Dish-washing machine	1/8 to 1/4	165 to 290	1/4	290
Ironing machine	1/4	290	1/4	290
Ice-cream freezer	1/2	535	1/2	535
Separator	1/8 to 1/4	165 to 290	1/6	210
Churn	1/8 to 3	165 to 2,640	1/4	290
Milk tester	1/12 to 1/8	125 to 165	1/8	165
Root cutter	1/4	290	1/4	290
Horse and sheep clippers	1/6 to 1/4	210 to 290	1/4	290
Grindstone	1/8 to 1/4	165 to 290	1/4	290
Milking machine	1 to 3	932 to 2,640	3	2,640
Corn sheller	3/4 to 1 1/2	746 to 1,400	1	990
Feed grinder	3 to 10	2,640 to 8,300	5	4,380
Emery wheel	1/4 to 1	290 to 932	1/4	290
Lathe	1/4 to 1/2	290 to 535	1/2	535
Silage cutter	10 to 25	8,300 to 20,700	15 to 20	12,400 to 16,600
Shredder and husker	10 to 20	8,300 to 16,600	15	12,400
Concrete mixer	2 to 10	1,864 to 8,300	5	4,380
Refrigeration	1/2 to 10	535 to 8,300	5	4,380
Cordwood saw	3 to 10	2,640 to 8,300	5	4,380
Pump, water	1/2 to 5	535 to 4,380	3	2,640

TABLE 6.—*Uses of electricity for heating*

[Trade data on power requirements]

Device	Power required	Average size used consumes—
	Watts	*Watts*
Electric flatiron	500 to 600	550
Electric toaster	350 to 500	450
Chafing dish (3-pint)	400 to 600	500
Coffee percolator (9-cup)	400 to 420	420
Waffle iron	600	600
Milk warmer (nursing bottles)	200 to 500	300
Hot plate	220 to 1,000	500
Curling iron	15 to 40	30
Warming pad	30 to 50	40
Bake ovens	600 to 1,800	1,500
Fireless cooker	500 to 660	600
Water heater (kitchen boiler)	500 to 3,000	2,500
Range	2,500 to 5,000	2,500

Electricity is used on the farm for light, power, and heat. Usually the first requirement is to light the buildings and driveways, and many small streams are capable of furnishing sufficient power to provide electricity for this purpose.

The uses of electricity for power and heating, together with the power requirement of each of a number of machines, are listed in

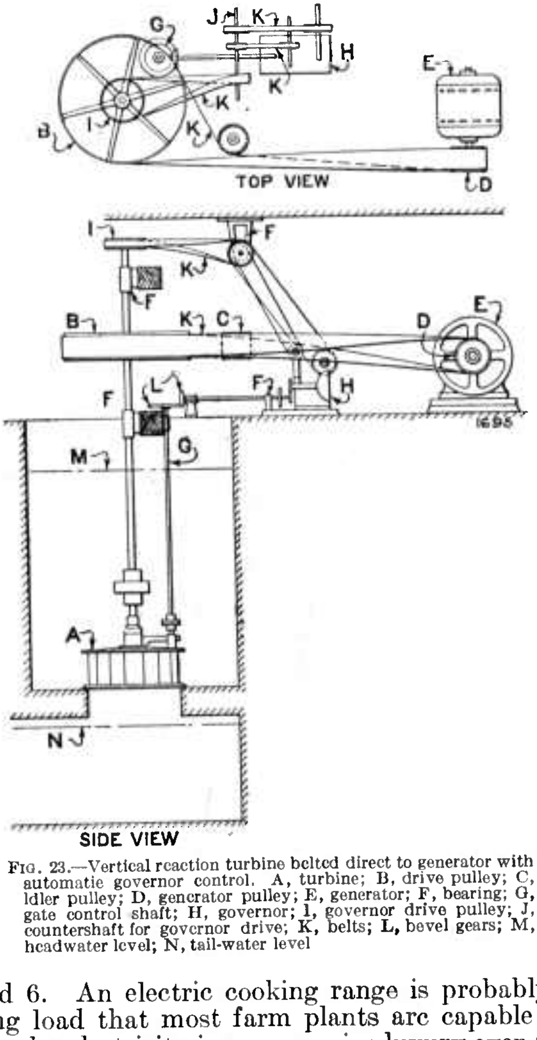

FIG. 23.—Vertical reaction turbine belted direct to generator with automatic governor control. A, turbine; B, drive pulley; C, idler pulley; D, generator pulley; E, generator; F, bearing; G, gate control shaft; H, governor; I, governor drive pulley; J, countershaft for governor drive; K, belts; L, bevel gears; M, headwater level; N, tail-water level

Tables 5 and 6. An electric cooking range is probably the largest single heating load that most farm plants are capable of handling. House heating by electricity is an expensive luxury even when current is obtained from a large hydroelectric plant. Therefore the heating of a house from a farm electric plant should not be considered, although a small electric heater might be used in the bathroom or other small room to take off the chill in the morning.

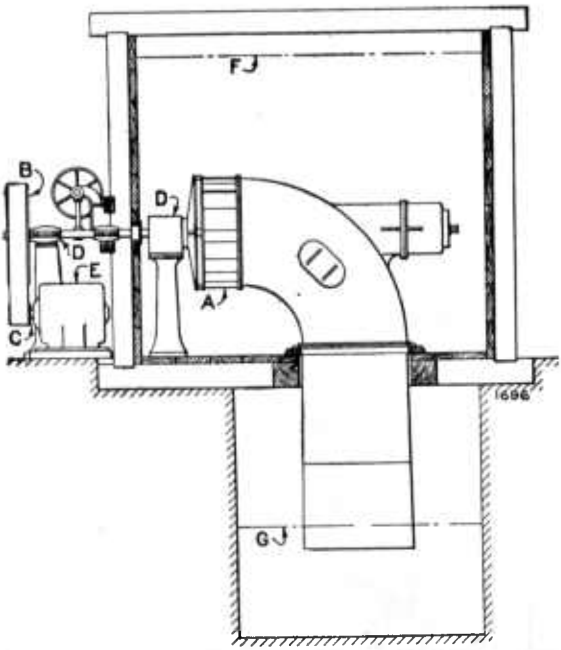

FIG. 24.—Horizontal reaction turbine mounted in a cast-iron quarter-turn draft tube and placed in timber-flume. This arrangement permits direct connection to a generator, or a pulley may be placed on the shaft for belt drive as shown. A, turbine; B, drive pulley; C, generator pulley; D, bearing; E, generator; F, headwater level; G, tail-water level

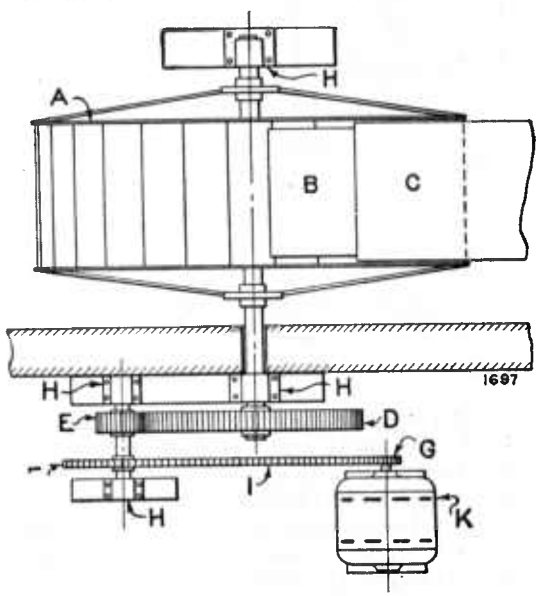

FIG. 25.—Overshot water wheel with roller chain drive. Where space does not permit belt drive and the line shaft is too far away for gear drive from the jackshaft, the difficulty may be overcome in this manner. A, water wheel; B, chute; C, flume; D, drive gear; E, pinion gear; F, drive sprocket; G, generator sprocket; H, bearings; I, roller sprocket chain; K, generator

By means of Figure 30 the number of lights required to illuminate a particular area may be determined as follows: Suppose the floor area of a living room is 288 square feet. This area is found on the scale on the left side of the chart. Following over horizontally to the radiating line for the living room, the figure at the bottom or top of the first vertical line to the right of this intersection indicates the number and size of lamps required for the most efficient use of current. The heavy line shows that for 288 square feet four 40-watt lamps are required, a total of 160 watts. The floor area of all other spaces to be illuminated and the wattage required should be similarly determined.

The lighting power and heating loads vary for every farm. In Tables 7, 8, and 9 are listed various items of electrical household and power equipment in an assumed liberally equipped farm installation with the number of watts required to operate each unit. In making an estimate of the watt requirements on any particular farm similar tables based on the data contained in Figure 30 and Tables 5 and 6 should be prepared.

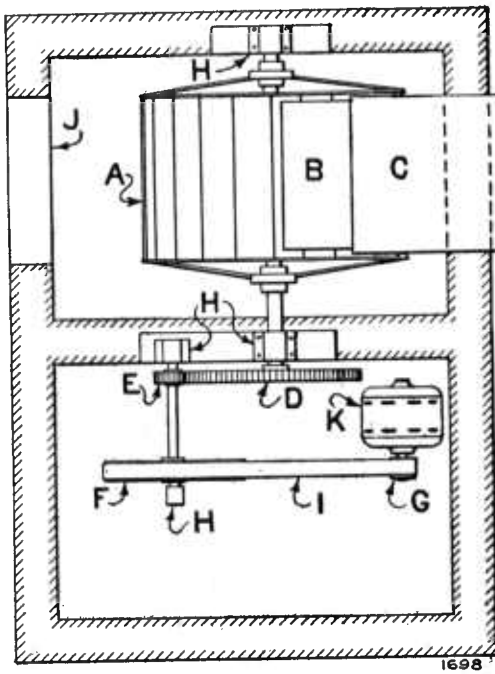

FIG. 26.—Overshot water wheel installation for driving a slow-speed generator. Note small number of gears and pulleys for stepping up the speed of the water-wheel shaft and compare with Figure 27. A, water wheel; B, chute; C, flume; D, drive gear; E, pinion gear; F, drive pulley; G, generator pulley; H, bearing; I, belt; J, discharge outlet; K, generator

It is more than probable that but a portion of the equipment listed in each of Tables 7, 8, and 9 will ever be in use at the same time. In determining the size of plant required those items of equipment in each table which are likely to be in use at one time should be listed and the wattage required for their operation totaled. It may be assumed that but 33⅓ percent of the house lamp wattage and 20 per cent of the outbuilding lamp wattage will ever be used at one time.

Thus in preparing an estimate for this assumed installation the total lighting load would be 644 watts, as indicated in Table 7. Assuming that, of the larger power units listed in Table 8, the washing machine, dish washer, water pump, and corn sheller might be in use at the same time, the power wattage required would be 3,435. In addition the electric range and the percolator (Table 9) might also be in use, adding 2,920 to the required wattage, the total then being 6,355 watts, necessitating a 7-kw. plant. If a plant of this size is not feasible, a smaller one may be installed together with the same items of equipment, provided care is taken that only units whose combined wattage requirements do not exceed the capacity of the plant are used at the same time.

TABLE 7.—*Sample lighting estimate*

Location of lamps	Area of space to be lighted, square feet	Lamps		Total watts	Simultaneous load
		Number	Size		
Living room	285	6	25	150	
Dining room	196	5	25	125	
Bedroom (first floor)	200	3	40	120	
Kitchen	167	5	25	125	
Laundry and wash room	120	2	25	50	
Bath	55	2	25	50	
Hall (downstairs)	56	1	25	25	
Storage pantry	28	1	25	25	
Cellar	456	3	25	75	
Bedroom	232	3	40	120	
Do	166	2	40	80	
Do	200	3	40	120	
Hall (upstairs)	85	1	25	25	
Porch (front)	216	1	40	40	
Porch (side)	228	1	40	40	
Porch (rear)	210	1	40	40	
Miscellaneous				160	
Total for house				1,370	
Per cent total watts in use at one time, 33⅓ per cent					457
Horse barn	1,000	8	25	200	
Cow barn	700	6	25	150	
Hog house	400	4	25	100	
Chicken house [1]	200	5	25	125	
Watering trough	100	1	40	40	
Front gate	100	1	40	40	
Barnyard entrance	100	1	40	40	
Dairy house	160	2	40	80	
Miscellaneous	160			160	
Total for outbuildings				935	
Per cent total watts in use at one time, 20 per cent					187
Total lighting load					644

[1] Lights to stimulate egg production.

TABLE 8.—*Sample power estimate*

Purpose	Horsepower of motor (Table 5)	Watts required (Table 5)	Simultaneous load
Washing machine	¼	290	
Vacuum cleaner	⅛	165	
Sewing machine	1/10	50	
Dishwasher	¼	290	
Ironing machine	¼	290	
Total for house		1,085	
Maximum watts required at one time			580
Separator	⅙	210	
Churn	¼	290	
Corn sheller	1	990	
Lathe	½	535	
Grindstone	¼	290	
Milking machine	3	2,640	
Water pump	2	1,865	
Total farm uses		6,820	
Maximum watts required at one time			2,855
Total power load			3,435

TABLE 9.—*Sample heating estimate*

Device	Watts (Table 6)	Simultaneous load
Electric flatiron	550	
Electric toaster	450	
Coffee percolator	420	
Hot plate	500	
Electric range	2,500	
Total	4,420	
Maximum in use at one time		2,920

AVAILABLE POWER SITES ON SELECTED STREAMS

Preliminary surveys were made on three typical streams in Virginia to obtain data with regard to the possibilities of small-stream development and to select sites for power plants from which electricity for light and power could be obtained for farms located near by. The streams surveyed were Cripple Creek in Wythe County, Mill Creek in Montgomery County, and Buchanan Creek in Washington County.

CRIPPLE CREEK PROJECTS

Figure 31 shows the section of Cripple Creek along which available power sites were located. Within a distance of 1.6 miles from the source, six sites are indicated. Each location requires different treatment owing to variations in the quantity of water available, the heads, and the surrounding conditions, but each site is more or less typical of those on many small streams.

Site No. 1.—Located near the source of the stream where the water supply was but 105 cubic feet per minute and the useful head $5\frac{1}{2}$ feet, this site presents a typical small-stream condition. There is too little energy to supply electric current direct from the generator, so that a storage battery must be used. Since there is a dam already in place, the installation of a water wheel, small generator, and storage battery would provide a plant that would compare favorably with a good engine-driven outfit of equal capacity at an estimated cost of about $750 [3] with a nickel-iron battery, or of about $600 if a lead-plate battery were used.

Site No. 2.—On this site an overshot water wheel now operates a flour mill intermittently on stored water. Further use of the water could be made by installing a small generator and storage battery which would operate simultaneously with the mill and not interfere therewith. It would provide electricity for lighting near-by homes at a reasonable cost and give the owner a satisfactory return on his investment.

Site No. 3.—A spring flowing 300 cubic feet per minute empties into a natural reservoir. A dam 4 feet high across the outlet of the creek would make possible a continuously operated plant of 1-kw. capacity without a storage battery, or the equivalent of the average farm-lighting plant. A higher dam would make possible a plant of greater capacity.

[3] In estimating the costs of this and the following projects no labor charge is included, it being assumed that the work will be done by farm help at times when not otherwise employed. It is further assumed that no expense for technical advice is to be incurred

Site No. 4.—The additional water from a spring below site No. 3 and the topography of the land offers an opportunity to supply one home with electricity for lighting and small power units, or three near-

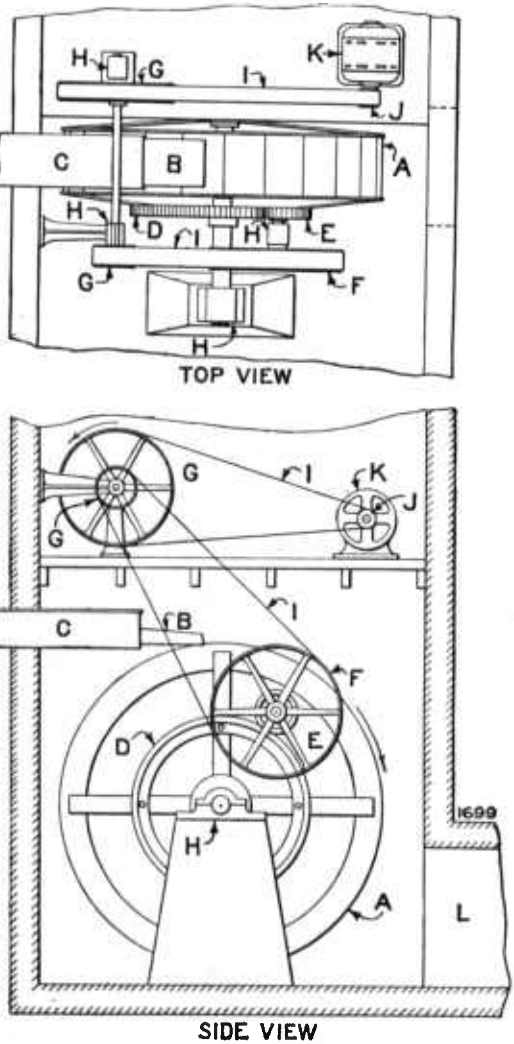

FIG. 27.—Overshot water-wheel installation for driving a high-speed generator. Note the additional pulleys and belt required to step-up the water-wheel shaft speed to that of the generator as compared with Figure 26. A, water wheel; B, chute; C, flume; D, drive gear; E, pinion gear; F, drive pulley; O, intermediate drive pulleys; H, bearing; I, belt: J, generator pulley; K, generator; L, discharge outlet

by houses with current for lighting. This plant would operate under a 7-foot head and 405 cubic feet of water per minute. A small inexpensive diversion dam and earth flume would make possible the development of a 2½-kw. plant, either by the owner or as a cooperative project, at an estimated cost of about $750.

Site No. 5.—At this point 405 cubic feet of water under a 9-foot head could be utilized. Although the conditions would permit of the installation of a plant of 3½-kw. capacity, from which the owner's residence near by and two residences one-half mile distant could be supplied with current, yet, owing to spring floods which would necessitate a substantial dam, it is doubtful whether the present demand

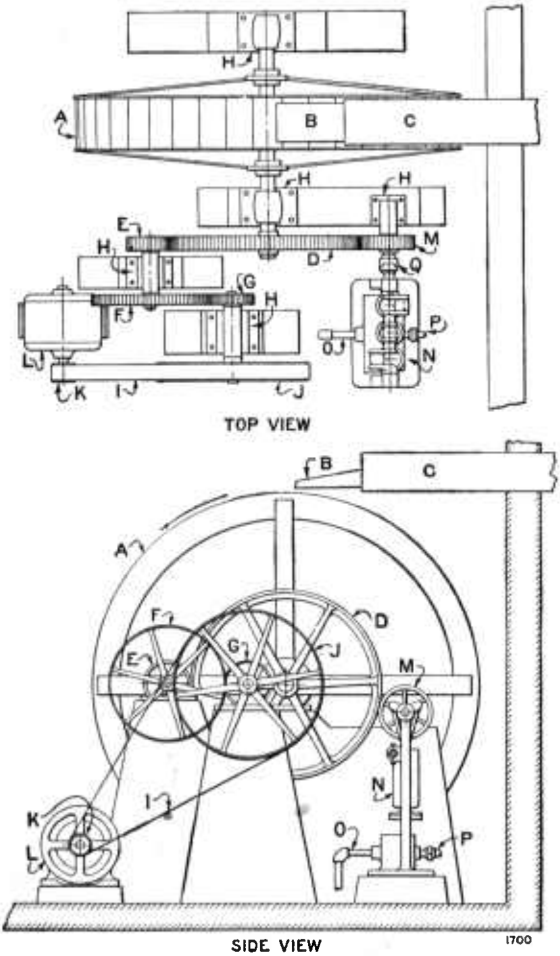

FIG. 28.—Overshot water-wheel installation showing combined water pump and generator drive. A, water wheel; B, chute; C, flume; D, main drive gear; E, main pinion gear; F, generator drive gear; G, generator pinion gear; H, bearing; I, belt; J, generator drive pulley; K, generator pulley; L, generator; M, pump drive pinion; N, triplex water pump; O, pump suction; P, pump discharge; Q, coupling for disconnecting pump

for current would warrant the development. If there were other residences to be supplied, sufficient current might be sold to afford a reasonably good return on the estimated cost of about $1,600.

Site No. 6.—An abandoned mill site, where the available head is 6½ feet and the volume 405 cubic feet per minute, could be repaired and with a 2½-kw. plant installed operated to supply two residences

with electric light and possibly some small power devices at an estimated cost of about $900.

MILL CREEK PROJECTS

Eight power sites were found on this stream in a stretch of 1½ miles. But three of these offered particularly interesting oppor-

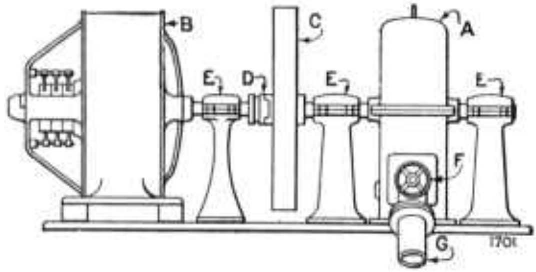

FIG. 29.—Impulse turbine direct connected to generator and pulley mounted on same shaft for belt drive to other machines. The jaw clutch permits easy disconnection of the generator in case the developed power is insufficient to operate all machines at the same time. A, impulseturbine; B, generator; C, pulley; D, coupling; E, bearing; F, control valve; G, supply pipe

tunities. Figures 32 and 33 show, respectively, a general and plan view of one site. The stone dam is in good condition and the old brick mill is in shape for the installation of the necessary machinery. It would be necessary to reconstruct the flume and to purchase and

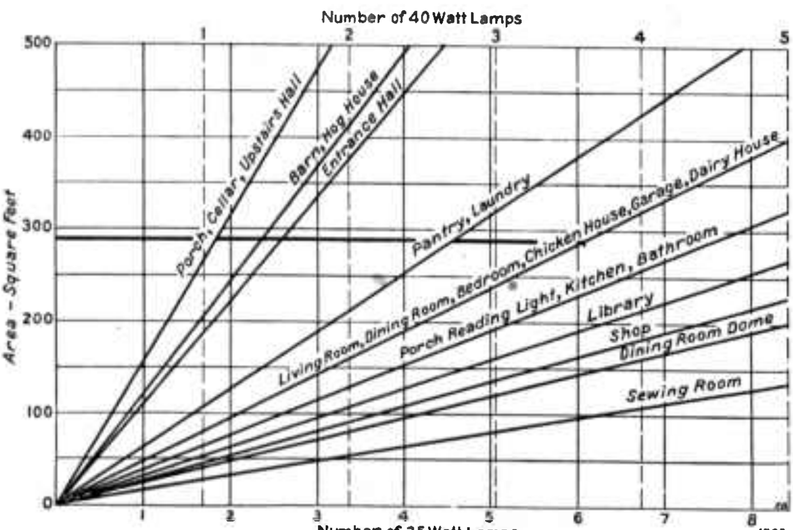

FIG. 30.—Chart for estimating the number and size of electric lamps required for different locations in order to obtain proper illumination and efficient use of current

install the equipment in order to provide the owner with electricity for lighting, cooking during part of the year, a small refrigerating plant, and other uses requiring a small amount of current. The volume of water available, 210 cubic feet of water per minute, under a 12-foot head would operate a plant of 2½-kw. capacity which might

be developed at an estimated cost of $710, or about $284 per kilowatt.

The second site is on the same property a short distance up stream from the first, and could be developed in conjunction with it at a total estimated cost of about $1,507. The volume of water at this point is 205 cubic feet per minute and the head 13 feet, which, with the power available at the lower site, would provide a combined output of 5 kilowatts. This would enable the owner to operate a cooking range throughout the year and a refrigerating plant of a capacity sufficient to enable him to market fresh meat at retail to near-by towns.

The third site is particularly interesting as it illustrates the possibility of more than one scheme of development. Figure 34 shows how a plant of 5-kilowatts capacity could be developed.

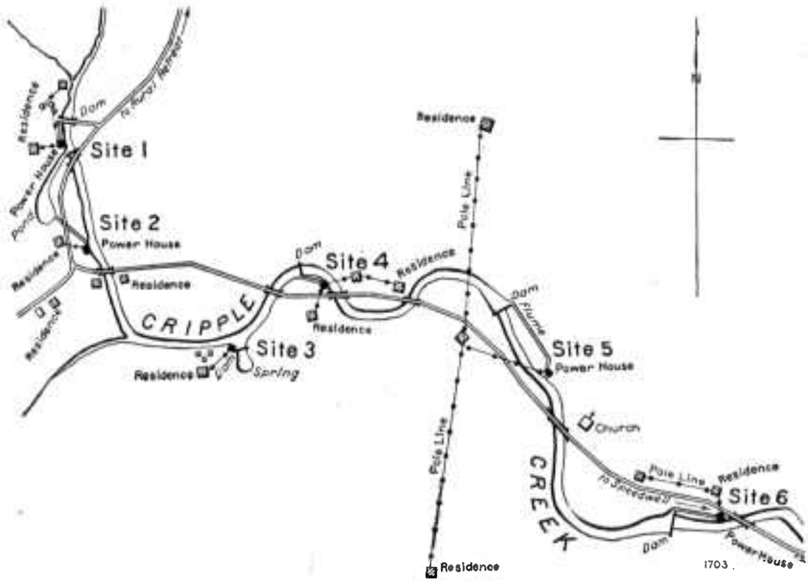

FIG. 31.—Farm power sites on Cripple Creek, Wythe County, Va.

Owing to the steep slope of the land it would be possible, by means of a dam 2 feet high, to obtain 180 cubic feet of water per minute with a 30-foot working head. The water would be conveyed to the plant, comparatively near the owner's residence, through an earth flume.

Sufficient electricity would be available at an estimated cost of $830, or about $166 per kilowatt, for lighting, cooking, water-pressure system, sawing wood, and for operating many other machines of medium power requirement. Or, in case the owner did not wish to install so large a plant, or did not care to invest so much money, the power house might be located farther up stream and nearer the owner's residence, as shown in Figure 35. The head would be but 11 feet, a loss of 19 feet, so that the capacity of the plant would be reduced to 2 kilowatts, the estimated cost being $475.

Another development of this site, but not nearly so economical as the others on this stream, previously described, is suggested in

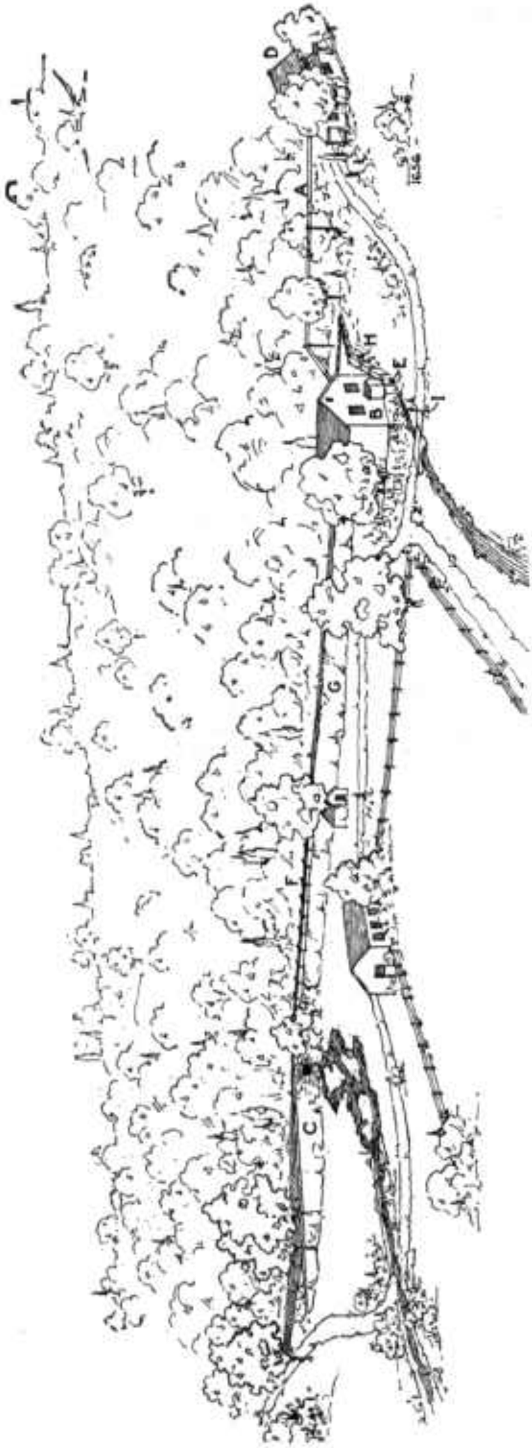

FIG. 32.—General view of an abandoned mill site on Mill Creek, Montgomery County, Va., which at reasonable cost could be reclaimed and developed as a water-power electric plant. A, transmission line; B, old mill building; C, stone dam; D, owner's residence; E, turbine pit; F, wood trough flume; G, earth flume, H, penstock; I, tailrace

Figure 36. This would provide a plant of 2-kilowatts capacity from a flow of 50 cubic feet of water under a 57-foot head, but the long pipe line would make it expensive. However, the pipe line would

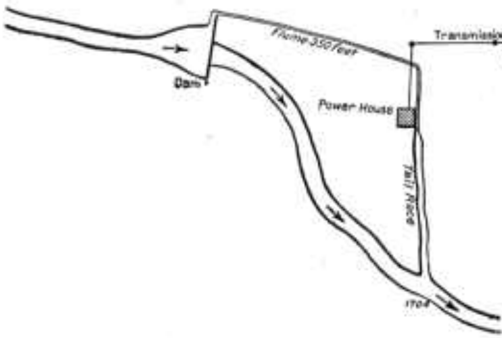

FIG. 33.—Plan view of site shown in Figure 32

conduct water under this high head directly to the owner's house and thus provide for excellent fire protection, which is always desirable.

BUCHANAN CREEK PROJECT

Figures 37 and 38 illustrate an installation on one of the smallest streams the development of which might be considered practicable. During dry periods the stream flow does not exceed 110 gallons per minute. A head of 15 feet can be obtained by building a 2-foot stone

FIG. 34.—Plan for developing, at the uppermost site on Mill Creek, a water-power electric plant of 5 kw. capacity operating on 180 cubic feet of water per minute under a 30-foot head

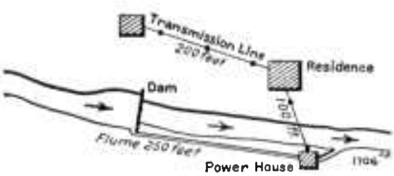

FIG. 35.—Plan for a less costly plant at the same site as shown in Figure 34

dam to form a storage basin between the hills that rise abruptly from the stream bed, and about 150 feet of earth channel for conducting the water to an overshot water wheel, 14 feet in diameter and 1 foot wide. This wheel would drive a 250-watt, 125-volt direct-current generator, from which current would be delivered to a 110-volt storage battery. The estimated cost of the development, including a nickel-iron battery, would be about $1,300. Ordinarily this project should not be favorably considered, since it involves the construction of a fairly long stone dam, the cost of which is not included in the above estimate. However, since materials are available at the dam site and the labor would be performed by the owner and his sons during spare time, the actual outlay would be such as would warrant the development. The plant would supply electricity to two residences for lighting and small power units. The estimated cost is greater than for the average small water-power plant, due primarily to the small quantity of water available and the distance from the power house to the residence.

SUCCESSFUL HIGH-HEAD PLANT

None of the sites surveyed and described in the foregoing pages offered an opportunity for a high-head plant. Sources of power are

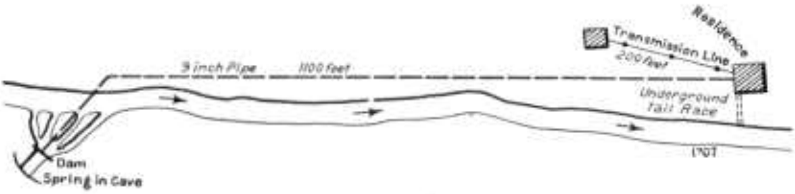

FIG. 36.—Another plan of development for the site shown in Figures 34 and 35

often found in springs issuing from points high up on hillsides. Frequently the spring flow can be utilized to operate an impulse turbine as indicated in Figures 39 and 40 which illustrate an exist-

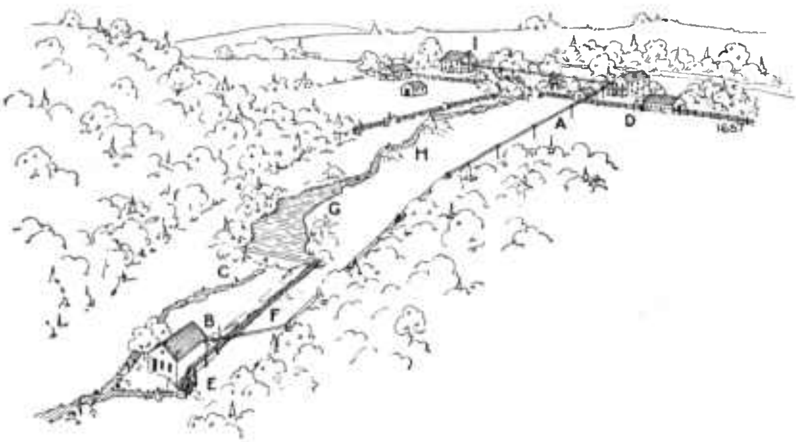

FIG. 37.—General view of proposed development on Buchanan Creek, Washington County, Va., to supply two residences with electricity. A, transmission line; B, power house; C, stream bed; D, owner's buildings; E, water wheel; F, flume; G, storage basin; H, spring-fed stream; I, neighbor's residence

ing installation of this type. The spring that supplies the water is situated about 1,500 feet from the house and 135 feet above the supply pipe at the wheel. The measurement of the flow from the spring was found to be only 30 gallons per minute.

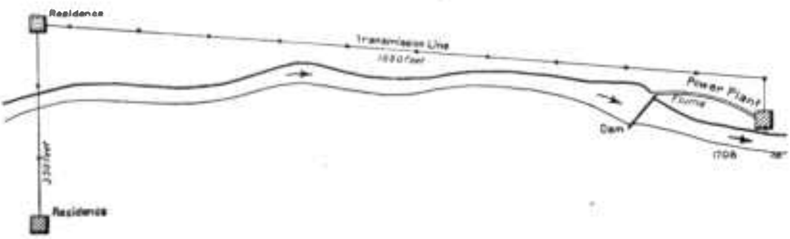

FIG. 38.—Plan view of site shown in Figure 37

A dam as indicated in Figure 40 was built high enough to impound sufficient water to operate the wheel for four hours continuously, this being the time required to charge the battery properly. The

installation consists of a 6-inch impulse water motor operating under a 100-foot working head; a 250-watt d. c. generator and a 16-cell 190-ampere-hour 32-volt lead-storage battery. The plant

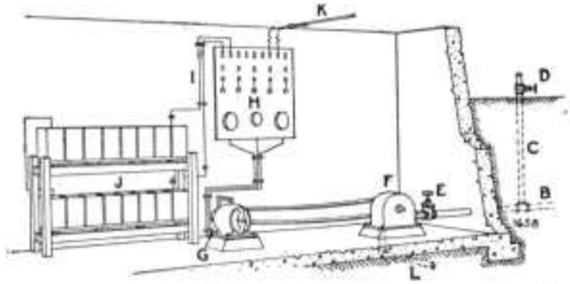

FIG. 39.—Equipment installed for development shown in Figure 40. B, underground supply pipe line; C, branch for fire protection; D, control valve to hose connection; E, control valve to water turbine; F, impulse turbine; G, generator; H, switchboard; I, battery charging line; J, storage battery; K, electric wires to lighting system

supplies the owner with electricity for lighting and small heating units, besides giving him fire protection by means of a valve-controlled outlet in the water pipe line.

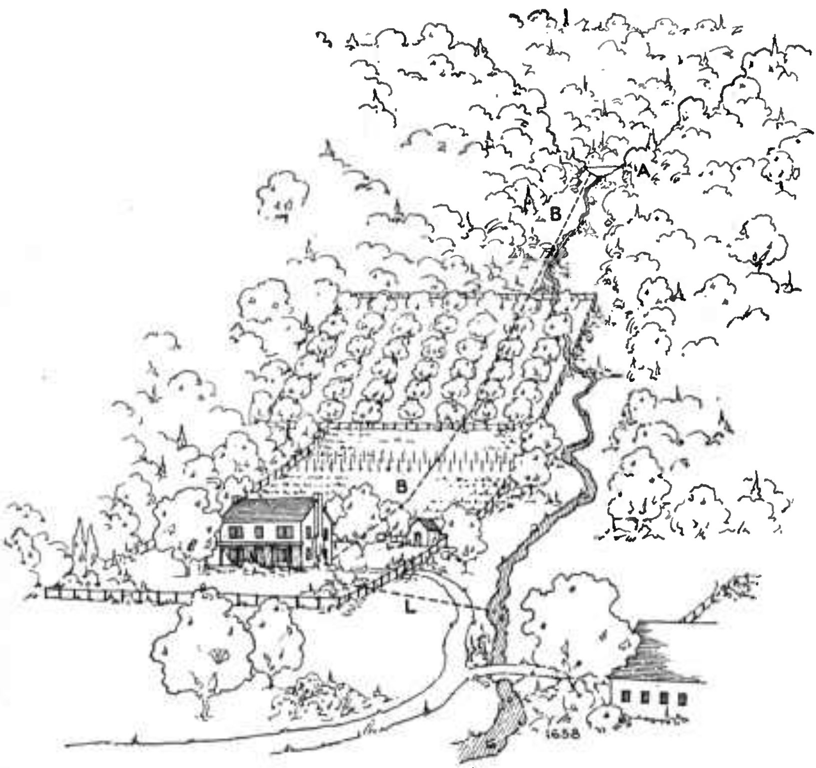

FIG. 40.—General view of high-head water power plant. A, dam; B, underground supply pipe line; L, underground tail-water pipe line

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